

SUMMER 2002 INVESTIGATIONS OF THE BENTHIC RECOLONIZATION STATUS OF RED CLAY DEPOSITS AT THE HARS

FINAL REPORT

March 2003

Contract No. GS-10F-0076J, SIN 899-1
SAIC Project No. 01-0440-01-8855-008

SAIC Report No. 631



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ACKNOWLEDGMENTS

This report presents the results of a series of surveys conducted during the summer of 2002 to investigate the physical and biological characteristics of red clay deposits at the Historic Area Remediation Site (HARS). These surveys were conducted by Science Applications International Corporation (SAIC) of Newport, RI, under contract to the U.S. Army Corps of Engineers–New York District (NYD). Dr. Stephen Knowles is the NYD’s manager of technical activities; Mr. Raymond Valente is SAIC’s program manager. Dr. Knowles provided logistical and planning support for the surveys, with assistance from Mr. Tim LaFontaine of the NYD’s Caven Point facility.

REMOTS sediment-profile imaging, benthic sampling and coring operations were conducted aboard the NYD’s M/V *Gelberman*. Side-scan sonar and sub-bottom profiling survey operations were conducted aboard the M/V *Beavertail*, of Jamestown, RI. The crews of the M/V *Gelberman* and M/V *Beavertail* are commended for their skill in vessel handling while conducting all survey operations, as well as their dedication during long hours of operation at the HARS.

The following SAIC staff participated in the field operations: Ben Allen, Brian Andrews, Pamela Luey, Kate Montgomery, John Morris, Natasha Pinckard, Kurt Rosenberger, Karen Shufeldt, Greg Tufts, Raymond Valente, Tom Waddington and Pamela Walter. Ocean Surveys, Inc. of Old Lyme, CT, under subcontract to SAIC, was responsible for providing vibracoring equipment and an experienced coring technician, Mr. Steve Godomski. Brian Andrews and Christine Seidel of SAIC were responsible for data tracking and management.

Applied Marine Science of League City, Texas, was responsible for the geotechnical analyses of the sediment core samples. Pace Analytical Services, Inc. of St. Paul, MN, (formerly Maxim Technologies, Inc.) conducted the total organic carbon (TOC) analyses of sediment core samples. Barry A. Vittor and Associates, Inc. (BVA) of Mobile, Alabama conducted the taxonomic analysis of the benthic grab samples.

Ray Valente prepared this report in conjunction with Pamela Walter, Brian Andrews, Natasha Pinckard, and Karen Hart. Michelle San Antonio and Megan Thomas were responsible for report production.

EXECUTIVE SUMMARY

In 1997, approximately one million cubic yards (yd³) of consolidated red clay dredged from Newark Bay was placed in the northeast quadrant of the former Mud Dump Site (MDS). Due to concerns about the ability of benthic organisms to colonize this cohesive red clay, a reconnaissance survey involving the collection of REMOTS sediment-profile images and plan view photographs (i.e., looking downward at the sediment surface) was conducted in October 1998. This survey indicated that the surface of the red clay was starting to become colonized by a benthic community comprised mainly of limited numbers of small, surface-dwelling, opportunistic species (Stage I successional stage). It was hypothesized that over time, the red clay would break down into smaller pieces and incorporate higher amounts of organic matter, thereby facilitating continued colonization by larger-bodied infauna (Stage III).

The follow-up investigation reported here was conducted during summer 2002 and involved collection of REMOTS and plan view images, benthic grab samples, side-scan sonar and sub-bottom profiling data, and sediment cores over the red clay deposit. The main objective was to characterize the existing physical and biological conditions over this deposit, particularly with respect to benthic recolonization status. For comparative purposes, samples also were collected at the South Reference Area located on natural sandy bottom 3 km south of the former MDS, as well as in a nearby area of the former MDS where normal, fine-grained dredged material had been placed during the same time period as the red clay (referred to as the Similar-Age Dredged Material Area, or SADMA).

The coring and acoustic sub-bottom profiling data showed that in the area where most of the red clay disposal activity had taken place, the resulting deposit of this material on the seafloor had a thickness ranging from 5 to 7 m. The side-scan sonar data revealed an absence of any distinct features denoting the presence of this material on the seafloor. In particular, there was a notable lack of any small-scale surface relief or roughness associated with the red clay deposit.

Consistent with the side-scan sonar data, the sediment-profile and plan view images indicated that the surface of the red clay deposit was much flatter and smoother in summer 2002 than it was in October 1998. Specifically, there was an absence of the larger, angular, cohesive chunks of clay that had been observed over this deposit in the earlier survey. In addition, it appeared that a thin layer or veneer of ambient silt, sand, and organic matter had become deposited on the surface of the red clay. It was hypothesized that the action of bottom currents and the burrowing activities of larger organisms have acted to break down the larger clay chunks over time. As the clay has weathered and the spaces among clay chunks have become filled with silt and sand, the surface of the deposit has become considerably smoother and more heterogeneous in composition.

The sediment-profile and plan view images indicated that both the SADMA and Red Clay Area had become recolonized by relatively abundant and diverse infaunal communities consisting of both surface-dwelling (i.e., Stages I and II) and deeper-burrowing (i.e., Stage III) organisms at the time of the summer 2002 survey. The images also indicated that there were numerous sessile and mobile epifauna living on the surface of the red clay, including crabs, starfish, and colonial hydroids.

EXECUTIVE SUMMARY (CONTINUED)

Taxonomic analysis of the benthic grab samples confirmed the REMOTS successional stage interpretations and indicated higher average organism abundance at the Red Clay and SADMA stations compared to the South Reference Area stations. The benthic communities in the Red Clay, SADMA, and South Reference Area differed significantly from each other in terms of both the types and relative proportions of infauna that were present. This was attributed to the significant differences that exist in the type of surface sediments occurring in each of these three areas. However, the SADMA and Red Clay Area were considered similar in terms of the *functional groups* of benthic organisms present (i.e., Stages I, II, and III).

LIST OF ACRONYMS

ANOSIM	analysis of similarities
ANOVA	analysis of variance
ASTM	American Standard Test Method
BVA	Barry A. Vittor and Associates, Inc.
CAD	confined aquatic disposal
CH ₄	Methane
CO ₂	Carbon dioxide
DAMOS	Disposal Area Monitoring System
DGPS	Differentially-corrected Global Positioning System
DIVERSE	program within PRIMER
Eh	electro-chemical potential
EPA	Environmental Protection Agency
GIS	Geographic Information System
GPS	Global Positioning System
HARS	Historic Area Remediation Site
kHz	kilohertz
LPIL	lowest practicable identification level
m ²	square meters
MDS	Mud Dump Site
mm	millimeter
m/sec	meters per second
M/V	Merchant Vessel
NAD 83	North American Datum of 1983
nMDS	non-metric Multi-dimensional scaling
NOAA	National Oceanic and Atmospheric Administration
NYD	New York District
OSI	Organism-Sediment Index
ppt	parts per thousand
pptr	parts per trillion
PRIMER	Plymouth Routines in Multivariate Ecological Research
QA/QC	quality assurance/quality control
QC	Quality Control
REMOTS	Remote Ecological Monitoring of the Seafloor
RPD	Redox Potential Discontinuity
USACE	U.S. Army Corps of Engineers
SADMA	Similar-Age Dredged Material Area
SAIC	Science Applications International Corporation
SIMPER	program within PRIMER
SMMP	Site Management and Monitoring Plan
TIFF	Tagged Image File Format
TOC	Total Organic Carbon
TVG	time varied gain
UTC	Universal Time Coordinate
yd ³	cubic yards

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1.0 INTRODUCTION

1.1 Background

Until September 1997, sediments dredged from New York Harbor were deposited in a portion of the New York Bight known as the Mud Dump Site (MDS), which was located about six nautical miles east of Sandy Hook, New Jersey. On September 1, 1997, the MDS and some surrounding historical dredged material disposal areas were redefined as the Historic Area Remediation Site (HARS; Figure 1.1-1). The EPA Region II and the U.S. Army Corps of Engineers (USACE) New York District (NYD) are jointly responsible for managing the HARS, primarily in an effort to reduce the elevated contamination and toxicity of surface sediments to acceptable levels. The two agencies have prepared a Site Management and Monitoring Plan (SMMP) for the HARS that identifies a number of actions, provisions, and practices to manage remediation activities and monitoring tasks.

During the summer and fall of 1997, approximately one million yd³ of consolidated red clay was placed in the northeast quadrant of the MDS. During the summer of 1997, prior to its official closure, conventional fine-grained dredged material was placed in the northwest quadrant of the former MDS. Because the fine-grained dredged material was placed at the former MDS at approximately the same time as the red clay, the area where it was deposited is referred to herein as the “Similar-Age Dredged Material Area” or SADMA (Figure 1.1-2).

The red clay was excavated from Newark Bay to create a series of Confined Aquatic Disposal (CAD) cells that have been used for containment of contaminated dredged material. In response to concerns about the ability of the cohesive red clay placed at the former MDS to provide habitat for benthic organisms, a REMOTS sediment-profile imaging survey was conducted in October 1998 to evaluate benthic recolonization status (SAIC 1998). This preliminary, reconnaissance survey indicated that the red clay had started to become colonized by a benthic community comprised mainly of limited numbers of small, surface-dwelling, opportunistic species (Stage I successional stage). It was hypothesized that over time the larger, cohesive chunks of red clay would eventually break down into smaller pieces and incorporate higher amounts of organic matter, thereby facilitating continued colonization by larger-bodied infauna.

1.2 2002 Survey Objectives

During the summer of 2002, a series of follow-up monitoring surveys were conducted to characterize in greater detail the existing physical and biological characteristics of the red clay deposits at the former MDS, approximately 5 years following the initial placement of this material. Specifically, the 2002 survey effort involved the following techniques and objectives:

- Side-scan sonar and sub-bottom profiling surveys were performed to estimate the thickness and broad-scale surface characteristics of the red clay deposits.
- Sediment cores were collected to evaluate the thickness and geotechnical characteristics of both the red clay and SADMA deposits.

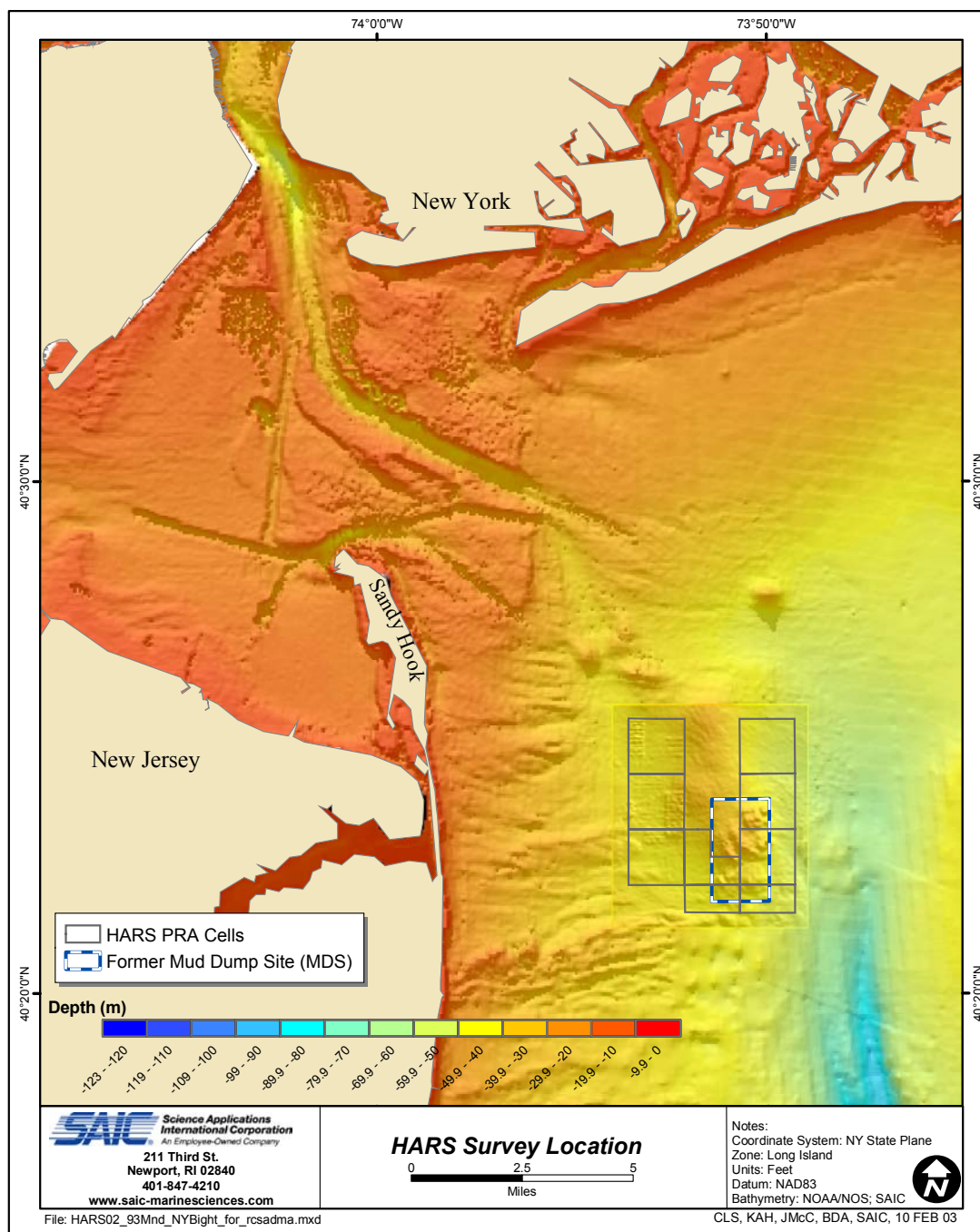


Figure 1.1-1. Map showing the locations of the former Mud Dump Site (MDS) and the Historic Area Remediation Site (HARS) in the New York Bight. The color-coded bathymetric data throughout the wide area surrounding the HARS are from the National Oceanic and Atmospheric Administration (NOAA) Coastal Relief Model Volume 1. The bathymetry at the HARS is from an SAIC survey conducted during summer 2002.

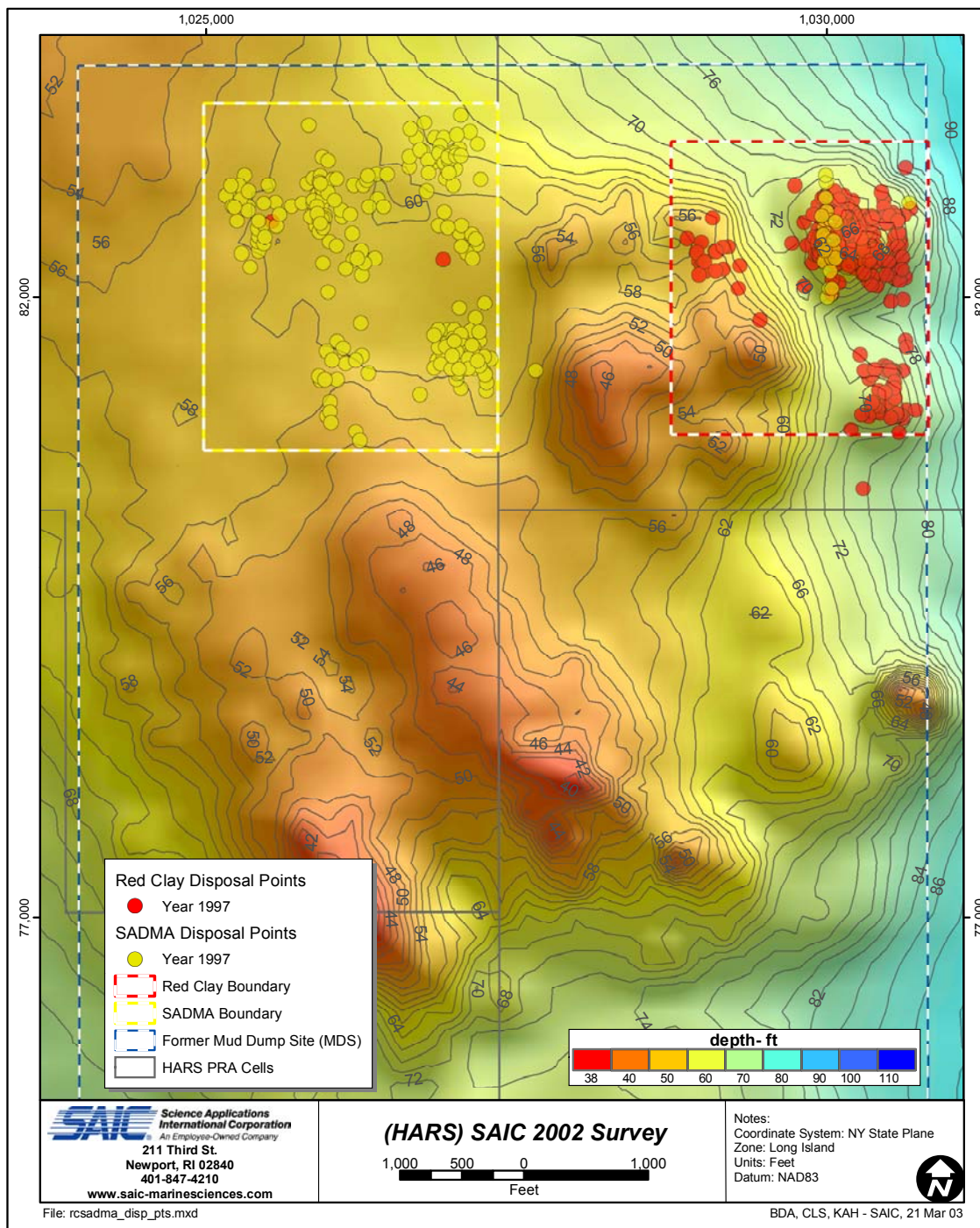


Figure 1.1-2. Map of the northern half of the former MDS showing the points where individual barge-loads of red clay and normal dredged material were placed in 1997. The underlying hill-shaded bottom topography is from a bathymetric survey of the HARS conducted by SAIC during the summer of 2002.

- REMOTS sediment-profile images, sediment plan view photographs, and benthic grab samples were collected to characterize the fine-scale physical characteristics of both the red clay and SADMA deposits and to evaluate, on a comparative basis, the degree to which these two types of material had become inhabited by benthic organisms.

To provide an additional basis for comparison, benthic grab samples, sediment-profile images, and sediment plan view photographs also were collected in the nearby South Reference Area, located approximately 3 km south of the HARS (Figure 1.2-1). In contrast to the SADMA and Red Clay Area, the surface sediment at the South Reference Area is comprised of homogenous, rippled fine sand, which is a substrate type that is common throughout much of the New York Bight.

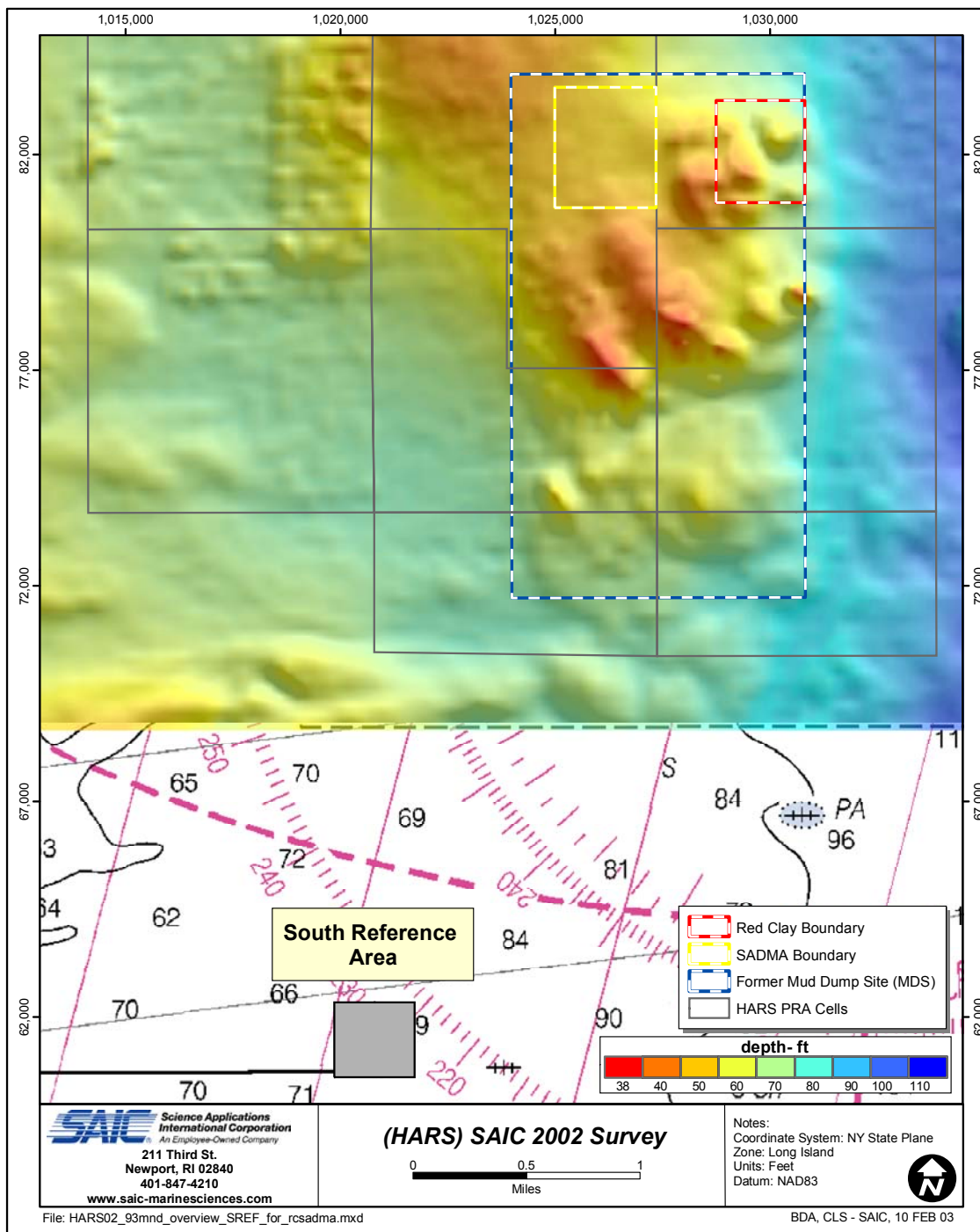


Figure 1.2-1. Map showing the locations of the red clay deposit area, the Similar-Age Dredged Material Area (SADMA), and the South Reference Area in relation to the boundaries of the former MDS and the HARS. Hill-shaded bottom topography is from the summer 2002 bathymetric survey of the HARS.

2.0 METHODS

2.1 Field Operations

The field operations took place between June 19 and September 9, 2002. The M/V *Beavertail* operated by P&M Marine Services of Jamestown, RI was used for the sub-bottom profiling and side-scan sonar surveys, while the M/V *Gelberman*, operated by the USACE NYD, was used for all the other survey work. Detailed descriptions of sample collection, sample processing, and data analysis methods are provided below for each of the following survey components: vessel navigation and positioning, side-scan sonar and sub-bottom profiling, REMOTS sediment-profile imaging and sediment plan view photography, benthic grab sampling, and sediment vibracoring.

2.2 Vessel Navigation and Positioning

Differentially-corrected Global Positioning System (DGPS) data in conjunction with Coastal Oceanographic's HYPACK[®] navigation and survey software were used to provide real-time vessel navigation to an accuracy of ± 3 m for each survey effort. A Trimble DSMPro GPS receiver was used to obtain raw satellite data and provide vessel position information in the horizontal control of North American Datum of 1983 (NAD 83). The DSMPro GPS unit also contains an integrated differential beacon receiver to improve overall accuracy of the satellite data to the necessary tolerances. The U.S. Coast Guard differential beacon broadcasting from Sandy Hook, NJ was utilized for real-time satellite corrections due to its geographic position relative to the HARS.

The DGPS data were ported to HYPACK[®] data acquisition software for position logging and helm display. The target stations and survey lanes were determined prior to the commencement of survey operations and stored in a project database. Throughout the survey, individual stations and survey lanes were selected and displayed to position the survey vessel at the correct geographic location for sampling. All single point samples were collected within a set radius of the target location. To remain on station during the coring survey, the survey vessel was occasionally anchored, in a 2-point configuration. The position of each sample was logged with a time stamp in Universal Time Coordinate (UTC) and a text identifier to facilitate Quality Control (QC) and rapid input into a Geographic Information System (GIS) database for display use. During the side-scan sonar and sub-bottom profiling surveys, lanes were set up and run within a ± 5 m window of the target center line. Vessel positioning was continuously logged during these surveys. DGPS navigation data were received, logged, and displayed in NAD 83 geographic coordinate system.

2.3 Side-Scan Sonar and Sub-bottom Profiling

2.3.1 Field Methods

The side-scan sonar and sub-bottom profiling surveys were conducted primarily along a series of north-south survey lanes that were run in early September 2002 over the red clay disposal area. Side-scan sonar and sub-bottom profiling data were acquired with a Datasonics/Benthos SIS-1000[®] combined digital sub-bottom profiling and side-scan sonar system.

The SIS-1000 side-scan sonar component operates at a swept frequency range of 90 to 110 kHz and the sub-bottom component operates at a swept frequency range of 2 to 7 kHz. The SIS-1000[®] fish was towed behind the survey vessel with an armored signal cable that provided power to the towfish and two-way communication with the SIS1000[®] topside data acquisition system. This system recorded acoustic data from the towfish and position information from the navigation system, and displayed real-time side-scan and sub-bottom imagery on a PC monitor connected to the topside acquisition system.

Side-scan sonar systems provide an acoustic image of the seafloor by detecting the strength of the backscatter returns from signals emitted from a towed transducer array. The side-scan transducers operate similar to a conventional depth-sounding transducer except that the towfish has a pair of opposing transducers aimed perpendicular to and directed on either side of the vessel track. Side-scan sonar data can reveal general seafloor characteristics and also determine the size and location of distinct objects. Dense objects (e.g., metal, rocks, hard sand seafloor areas) will reflect strong signals and appear as dark areas in the records presented in this report. Conversely, areas characterized by soft features (e.g., silt or mud sediments), which absorb sonar energy, appear as light areas in the sample records.

Sub-bottom profiling is a standard technique used for distinguishing and measuring various sediment layers that exist below the sediment/water interface. Sub-bottom systems are able to distinguish these sediment layers by measuring differences in acoustic impedance between them. Acoustic impedance is a function of the density of a layer and the speed of sound within that layer; it is affected by differences in grain size, roughness, and porosity. Sound energy transmitted to the seafloor is reflected off the boundaries between sediment layers of different acoustic impedance. A sub-bottom system uses the energy reflected from these boundary layers to build the image. The depth of penetration and the degree of resolution of a sub-bottom system depends on the frequency and pulse width of the acoustic signal and the characteristics of the various layers encountered.

2.3.2 Side-Scan Sonar Data Processing and Analysis

During acquisition, the data from each survey lane were saved into separate files to facilitate post-processing. During post-processing, each lane was re-played using the Chesapeake Technologies SonarWeb[®] software package. Water column and time varied gain (TVG) adjustments were made, and then the data were merged together using the SonarWeb[®] mosaic utility. After the mosaic was completed, it was saved and exported as a geo-referenced TIFF (Tagged Image File Format) file. This TIFF file was then used for a variety of subsequent analysis techniques.

2.3.3 Sub-bottom Profiling Data Processing and Analysis

During acquisition, the data from each survey lane were saved into a separate file to facilitate post-processing. After data acquisition, the sub-bottom data were analyzed and edited as necessary using the SonarWeb[®] software. SonarWeb[®] allowed manual detection, tracking, and digitizing of any sub-bottom layers that were present in the data and also allowed the data to be re-displayed under a variety of different configurations.

2.4 REMOTS Sediment-Profile and Plan View Imaging

2.4.1 Sampling Design and Field Methods

At the end of June 2002, REMOTS sediment-profile images and corresponding sediment plan view photographs were collected at a total of 70 stations located over the red clay deposits in the northeast quadrant of the former MDS (Figure 2.4-1 and Table 2.4-1). These are the same 70 stations that were sampled in the October 1998 REMOTS survey of these red clay deposits (SAIC 1998). REMOTS and plan view images also were collected at an additional 6 stations located in the SADMA (Figure 2.4-1 and Table 2.4-1); these stations are a subset of those sampled in the SADMA during the October 1998 survey. Finally, images also were collected at 10 stations located in the South Reference Area (see Figure 1.1-2 and Table 2.4-2).

During all survey operations, at least two replicate REMOTS sediment-profile images and one corresponding plan view image were collected at each station. Color slide film was used and processed at the end of each field day using a portable processor to verify proper equipment operation and image acquisition.

2.4.2 REMOTS Sediment-Profile Image Acquisition

REMOTS is a formal and standardized technique for sediment-profile imaging and analysis (Rhoads and Germano 1982; 1986). A Benthos Model 3731 Sediment-Profile Camera (Benthos, Inc., North Falmouth, MA) was used in this study (Figure 2.4-2). The camera is designed to obtain *in situ* profile images of the top (20 cm) of seafloor sediment. Functioning like an inverted periscope, the camera consists of a wedge-shaped prism with a front faceplate and a back mirror mounted at a 45-degree angle to reflect the profile of the sediment-water interface facing the camera (Figure 2.4-2). The prism is filled with distilled water, the assembly contains an internal strobe for illumination, and a 35-mm camera is mounted horizontally on top of the prism. The prism assembly is moved up and down into the sediments by producing tension or slack on the winch wire. Tension on the wire keeps the prism in the up position, out of the sediment.

The camera frame is lowered to the seafloor at a rate of approximately 1 m/sec (Figure 2.4-2). When the frame settles onto the seafloor, slack on the winch wire allows the prism to penetrate the seafloor vertically. A passive hydraulic piston ensures that the prism enters the bottom slowly (approximately 6 cm/sec) and does not disturb the sediment-water interface. As the prism starts to penetrate the seafloor, a trigger activates a 13-second time delay on the shutter release to allow maximum penetration before a photo is taken.

A Benthos Model 2216 Deep Sea Pinger attached to the camera outputs a 12 kHz signal once per second; upon discharge of the camera strobe, the ping rate doubles for a period of 10 seconds. By monitoring the pinger's repetition rate from the surface vessel, it is possible to confirm that a successful image was obtained. Because the sediment photographed is directly against the face plate, turbidity of the ambient seawater does not affect image quality. When the camera is raised, a wiper blade cleans off the faceplate, the film is advanced by a motor drive, the strobe is recharged, and the camera can be lowered for another image. At least two replicate sediment-profile images were obtained at each station using color slide film (Kodak Ektachrome).

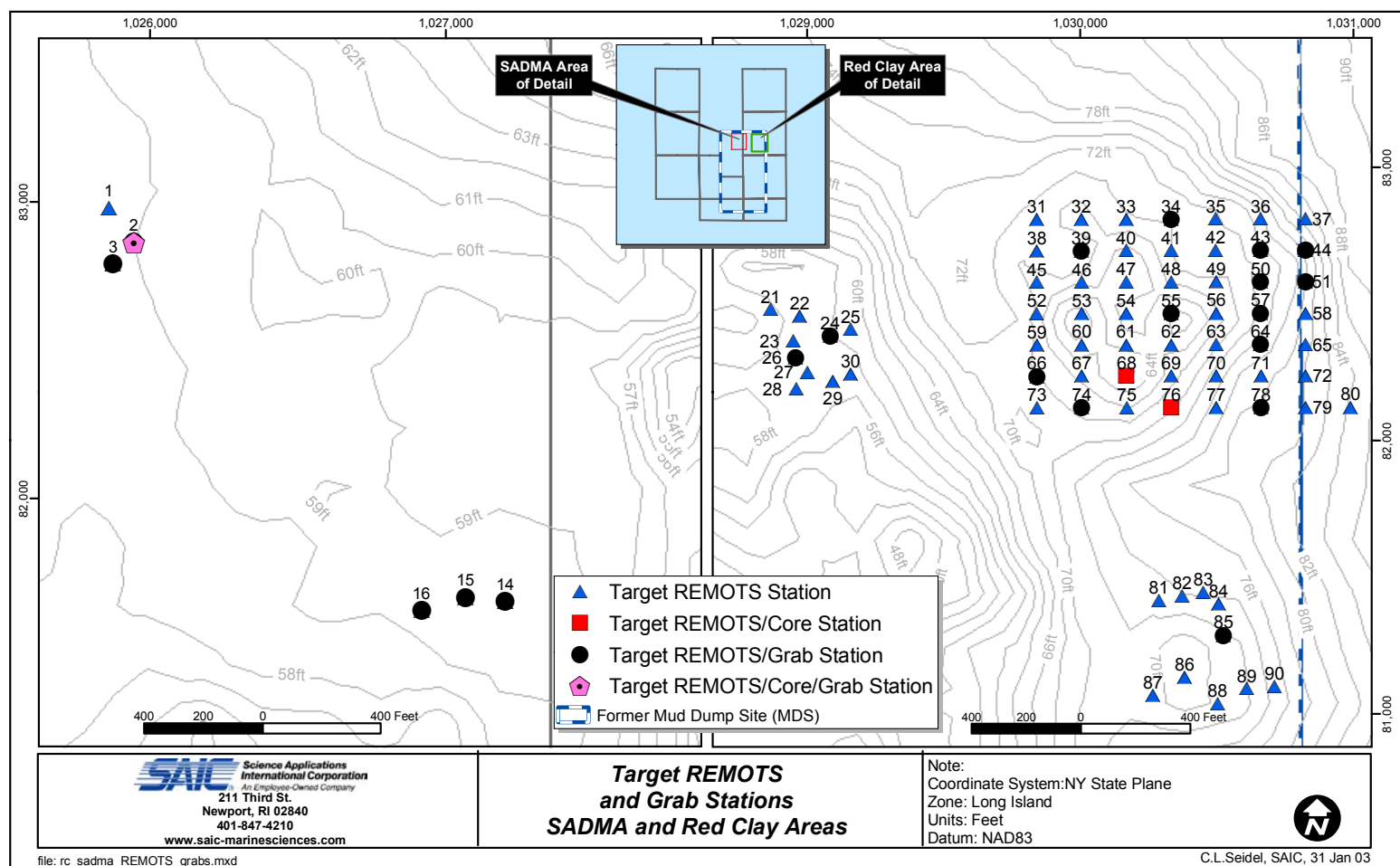


Figure 2.4-1. Map showing stations in the SADMA and Red Clay Area where REMOTS sediment-profile and plan view images were collected in June 2002. Stations in the Red Clay Area were concentrated over the three locations of the most intense disposal activity (see Figure 1.1-2). Stations where benthic grab and vibracore samples were collected (in addition to the REMOTS and planview images) are also indicated.

Table 2.4-1.
Coordinates of REMOTS/Plan View Stations in the SADMA and Red Clay Area
(Shading indicates stations where benthic grab samples also were collected)

Station	Latitude	Longitude	Northing	Easting	Station	Latitude	Longitude	Northing	Easting
Red Clay					Red Clay				
21	40.3930	73.8398	82480	1028866	60	40.3926	73.8357	82351	1030005
22	40.3929	73.8395	82456	1028972	61	40.3926	73.8352	82351	1030169
23	40.3926	73.8395	82365	1028949	62	40.3926	73.8346	82352	1030333
24	40.3927	73.8391	82384	1029084	63	40.3926	73.8340	82352	1030497
25	40.3928	73.8388	82408	1029158	64	40.3926	73.8334	82352	1030661
26	40.3925	73.8395	82304	1028959	65	40.3926	73.8328	82352	1030825
27	40.3923	73.8394	82250	1029001	66	40.3923	73.8363	82236	1029841
28	40.3922	73.8395	82189	1028959	67	40.3923	73.8357	82236	1030005
29	40.3922	73.8390	82220	1029094	68	40.3923	73.8352	82236	1030169
30	40.3923	73.8388	82244	1029159	69	40.3923	73.8346	82237	1030333
31	40.3939	73.8363	82810	1029840	70	40.3923	73.8340	82237	1030497
32	40.3939	73.8357	82810	1030004	71	40.3923	73.8334	82237	1030661
33	40.3939	73.8352	82811	1030168	72	40.3923	73.8328	82238	1030825
34	40.3939	73.8346	82811	1030332	73	40.3920	73.8363	82121	1029841
35	40.3939	73.8340	82811	1030496	74	40.3920	73.8357	82121	1030005
36	40.3939	73.8334	82812	1030660	75	40.3920	73.8352	82122	1030169
37	40.3939	73.8328	82812	1030824	76	40.3920	73.8346	82122	1030333
38	40.3935	73.8363	82695	1029840	77	40.3920	73.8340	82122	1030497
39	40.3935	73.8357	82695	1030004	78	40.3920	73.8334	82123	1030661
40	40.3935	73.8352	82696	1030168	79	40.3920	73.8328	82123	1030826
41	40.3935	73.8346	82696	1030332	80	40.3920	73.8322	82123	1030990
42	40.3935	73.8340	82696	1030496	81	40.3900	73.8347	81414	1030288
43	40.3935	73.8334	82697	1030660	82	40.3901	73.8344	81433	1030372
44	40.3935	73.8328	82697	1030825	83	40.3901	73.8342	81445	1030451
45	40.3932	73.8363	82580	1029840	84	40.3900	73.8340	81403	1030507
46	40.3932	73.8357	82581	1030004	85	40.3897	73.8339	81287	1030525
47	40.3932	73.8352	82581	1030169	86	40.3893	73.8344	81135	1030382
48	40.3932	73.8346	82581	1030333	87	40.3891	73.8348	81068	1030266
49	40.3932	73.8340	82582	1030497	88	40.3890	73.8340	81038	1030503
50	40.3932	73.8334	82582	1030661	89	40.3891	73.8336	81093	1030609
51	40.3932	73.8328	82582	1030825	90	40.3892	73.8332	81099	1030711
52	40.3929	73.8363	82465	1029841	SADMA				
53	40.3929	73.8357	82466	1030005	1	40.3943	73.8506	82979	1025861
54	40.3929	73.8352	82466	1030169	2	40.3940	73.8503	82864	1025945
55	40.3929	73.8346	82466	1030333	3	40.3938	73.8506	82791	1025875
56	40.3929	73.8340	82467	1030497	14	40.3907	73.8458	81652	1027200
57	40.3929	73.8334	82467	1030661	15	40.3907	73.8463	81663	1027066
58	40.3929	73.8328	82467	1030825	16	40.3906	73.8468	81621	1026917
59	40.3926	73.8363	82351	1029841					

Table 2.4-2.

Coordinates of REMOTS and Plan View Stations at the South Reference Area (NAD 83)
(Shading indicates stations where benthic grab samples also were collected)

Station	Latitude	Longitude	Northing	Easting
SREF3	40.3372	73.8711	62150	1020175
SREF4	40.3372	73.8670	62152	1021324
SREF5	40.3367	73.8700	61987	1020504
SREF8	40.3358	73.8700	61658	1020504
SREF9	40.3358	73.8694	61659	1020668
SREF10	40.3358	73.8676	61659	1021160
SREF11	40.3354	73.8711	61494	1020176
SREF14	40.3340	73.8711	61002	1020177
SREF16	40.3340	73.8694	61002	1020669
SREF18	40.3340	73.8682	61003	1020997
SREF20	40.3336	73.8670	60839	1021326

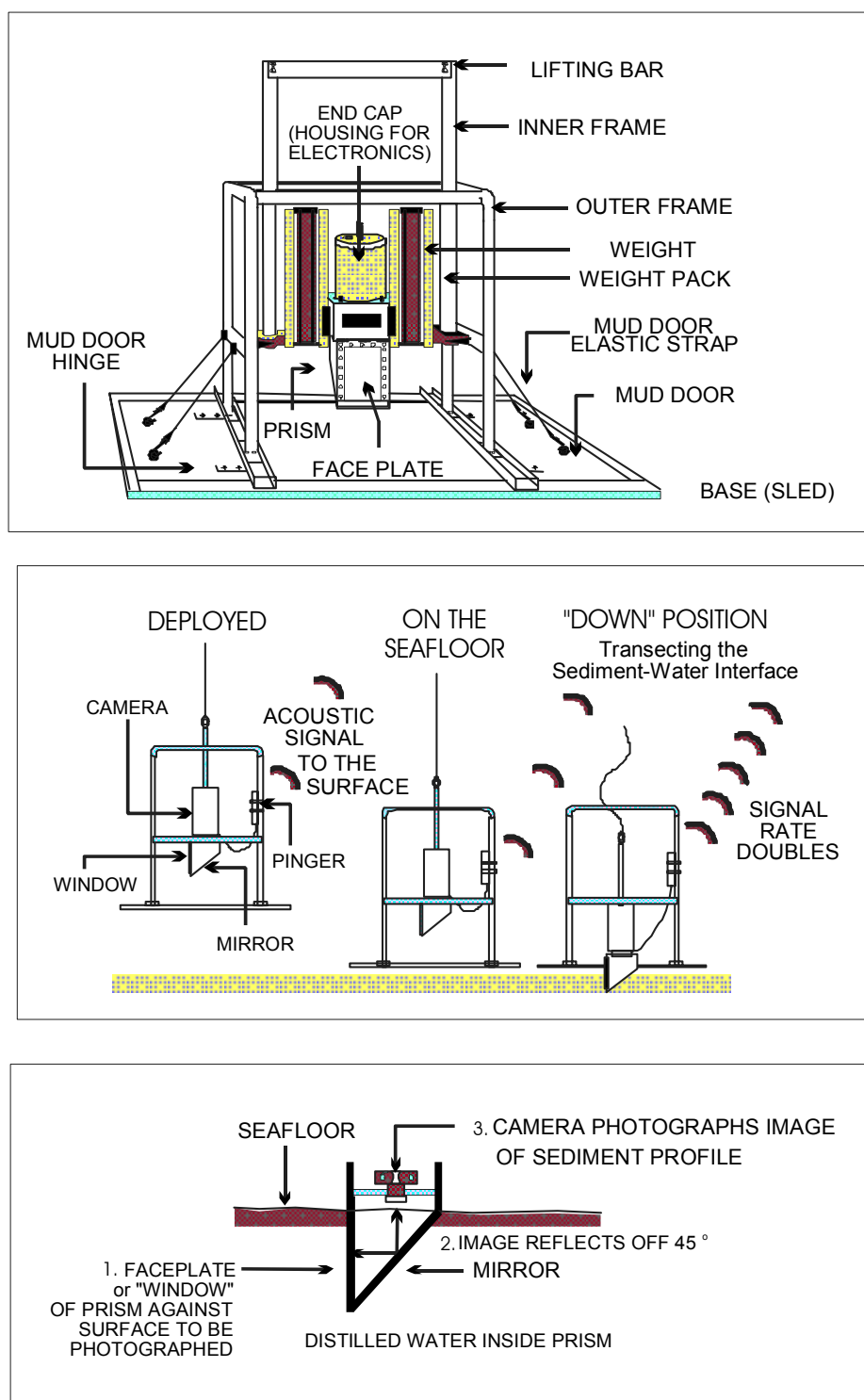


Figure 2.4-2. Schematic diagram of Benthos, Inc. Model 3731 REMOTS sediment-profile camera and sequence of operation on deployment

The film was developed at the end of each day of field operations to verify that the equipment was operating properly and all necessary data were acquired.

2.4.3 REMOTS Sediment-Profile Image Analysis

A computerized image analysis system was used to analyze the images. The original sediment-profile images (35-mm slides) were scanned and imported digitally into the image analysis system for measurement of a suite of up to 21 standard biological and physical parameters. The data for each image were stored automatically in a centralized database and exported in various formats (data tables and reports) to be compared statistically and mapped using Arcview® GIS. All measurements were reviewed (quality assurance check) before being approved for final data synthesis, statistical analyses, and interpretation. Summaries of the standard REMOTS measurement parameters presented in this report are presented below.

2.4.3.1 Sediment Type Determination

The sediment grain-size major mode and range are estimated visually from the photographs by overlaying a grain size comparator of the same scale. This comparator was prepared by photographing a series of Udden-Wentworth size classes (equal to or less than coarse silt up to granule and larger sizes) through the REMOTS sediment-profile camera. Seven grain size classes are on this comparator: >4 phi, 4 to 3 phi, 3 to 2 phi, 2 to 1 phi, 1 to 0 phi, 0 to -1 phi, and <-1 phi. Table 2.4-3 is provided to allow conversion of phi units to other commonly used grain size scales. The lower limit of optical resolution of the photographic system is about 62 microns (4 phi), allowing recognition of grain sizes equal to or greater than coarse silt. The accuracy of this method has been documented by comparing REMOTS sediment-profile image estimates with grain size statistics determined from laboratory sieve analyses.

The major modal grain size that is assigned to an image is the dominant grain size as estimated by area within the imaged sediment column. In those images that show layering of sand and mud, the dominant major mode assigned to a replicate therefore depends on how much area of the image is represented by sand versus mud. These textural assignments may or may not correspond to traditional sieve analyses depending on how closely the vertical sampling intervals are matched between the grab or core sample and the depth of the imaged sediment. Layering is noted as a comment accompanying the REMOTS sediment-profile image data file.

2.4.3.2 Benthic Habitat Classification

Based on extensive past REMOTS sediment-profile imaging experience in coastal New England, five basic benthic habitat types have been found to exist in shallow-water estuarine and open-water near shore environments: AM = Ampelisca mat, SH = shell bed, SA = hard sand bottom, HR = hard rock/gravel bottom, and UN = unconsolidated soft bottom (Table 2.4-4). Several sub-habitat types exist within these major categories (Table 2.4-4). Each of the REMOTS sediment-profile images obtained in the present study was assigned one of the habitat categories listed in Table 2.4-4.

Table 2.4-3.
Grain Size Scales for Sediments

ASTM (Unified) Classification ¹	U.S. Std. Mesh ²	Size in mm	PHI Size	Wentworth Classification ³
Boulder	12 in (300 mm)	4096.	-12.0	Boulder
		1024.	-10.0	
		256.	-8.0	Large Cobble
		128.	-7.0	
Cobble	3 in. (75 mm)	107.64	-6.75	
		90.51	-6.5	Small Cobble
		76.11	-6.25	
		64.00	-6.0	
Coarse Gravel	3/4 in (19 mm)	53.82	-5.75	
		45.26	-5.5	Very Large Pebble
		38.05	-5.25	
		32.00	-5.0	
		26.91	-4.75	
		22.63	-4.5	Large Pebble
		19.03	-4.25	
		16.00	-4.0	
		13.45	-3.75	
		11.31	-3.5	Medium Pebble
		9.51	-3.25	
		8.00	-3.0	
	2.5	6.73	-2.75	
	3	5.66	-2.5	Small Pebble
	3.5	4.76	-2.25	
	4	4.00	-2.0	
Coarse Sand	5	3.36	-1.75	
	6	2.83	-1.5	Granule
	7	2.38	-1.25	
	8	2.00	-1.0	
	10	1.68	-0.75	
	12	1.41	-0.5	Very Coarse Sand
	14	1.19	-0.25	
Medium Sand	16	1.00	0.0	
	18	0.84	0.25	
	20	0.71	0.5	Coarse Sand
	25	0.59	0.75	
	30	0.50	1.0	
	35	0.420	1.25	
	40	0.354	1.5	Medium Sand
	45	0.297	1.75	
	50	0.250	2.0	
Fine Sand	60	0.210	2.25	
	70	0.177	2.5	Fine Sand
	80	0.149	2.75	
	100	0.125	3.0	
	120	0.105	3.25	
	140	0.088	3.5	Very Fine Sand
	170	0.074	3.75	
Fine-grained Soil: Clay if $PI \geq 4$ Silt if $PI < 4$	200	0.0625	4.0	
	230	0.0526	4.25	
	270	0.0442	4.5	Coarse Silt
	325	0.0372	4.75	
	400	0.0312	5.0	Medium Silt
		0.0156	6.0	Fine Silt
		0.0078	7.0	Very Fine Silt
		0.0039	8.0	Coarse Clay
		0.00195	9.0	Medium Clay
		0.00098	10.0	Fine Clay
		0.00049	11.0	
		0.00024	12.0	
		0.00012	13.0	
		0.000061	14.0	

1. ASTM Standard D 2487-92. This is the ASTM version of the Unified Soil Classification System. Both systems are similar (from ASTM (1993)).

2. Note that British Standard, French, and German DIN mesh sizes and classifications are different.

3. Wentworth sizes (in inches) cited in Krumbein and Sloss (1963).

Source: U.S. Army Corps of Engineers. (1995). Engineering and Design Coastal Geology, "Engineer Manual 1110-2-1810, Washington, D.C.

Table 2.4-4.
Benthic Habitat Categories Assigned to
Sediment-Profile Images Obtained in this Study

<p>Habitat AM: <i>Ampelisca</i> Mat Uniformly fine-grained (i.e., silty) sediments having well-formed amphipod (<i>Ampelisca</i> spp.) tube mats at the sediment-water interface.</p>
<p>Habitat SH: Shell Bed A layer of dead shells and shell fragments at the sediment surface overlying sediment ranging from hard sand to silts. Epifauna (e.g., bryozoans, tube-building polychaetes) commonly found attached to or living among the shells. Two distinct shell bed habitats: SH.SI: Shell Bed over silty sediment - shell layer overlying sediments ranging from fine sands to silts to silt-clay. SH.SA: Shell Bed over sandy sediment - shell layer overlying sediments ranging from fine to coarse sand.</p>
<p>Habitat SA: Hard Sand Bottom Homogeneous hard sandy sediments, do not appear to be bioturbated, bedforms common, successional stage mostly indeterminate because of low prism penetration. SA.F: Fine sand - uniform fine sand sediments (grain size: 4 to 3 phi). SA.M: Medium sand - uniform medium sand sediments (grain size: 3 to 2 phi). SA.G: Medium sand with gravel - predominately medium to coarse sand with a minor gravel fraction.</p>
<p>Habitat HR: Hard Rock/Gravel Bottom Hard bottom consisting of pebbles, cobbles and/or boulders, resulting in no or minimal penetration of the REMOTS camera prism. Some images showed pebbles overlying silty-sediments. The hard rock surfaces typically were covered with epifauna (e.g., bryozoans, sponges, tunicates).</p>
<p>Habitat UN: Unconsolidated Soft Bottom Fine-grained sediments ranging from very fine sand to silt-clay, with a complete range of successional stages (I, II and III). Biogenic features were common (e.g., amphipod and polychaete tubes at the sediment surface, small surface pits and mounds, large borrow openings, and feeding voids at depth). Several sub-categories: UN.SS: Fine Sand/Silty - very fine sand mixed with silt (grain size range from 4 to 2 phi), with little or no shell hash. UN.SI: Silty - homogeneous soft silty sediments (grain size range from >4 to 3 phi), with little or no shell hash. Generally deep prism penetration. UN.SF: Very Soft Mud - very soft muddy sediments (>4 phi) of high apparent water content, methane gas bubbles present in some images, deep prism penetration.</p>

2.4.3.3 Mud Clasts

When fine-grained, cohesive sediments are disturbed, either by physical bottom scour or faunal activity (e.g., decapod foraging), intact clumps of sediment are often scattered about the seafloor. These mud clasts can be seen at the sediment-water interface in REMOTS sediment-profile images. During image analysis, the number of clasts are counted, the diameter of a typical clast is measured, and their oxidation state is assessed. Depending on their place of origin and the depth of disturbance of the sediment column, mud clasts can be reduced or oxidized. Also, once at the sediment-water interface, these sediment clumps are subject to bottom-water oxygen levels and bottom currents. Based on laboratory microcosm observations of reduced sediments placed within an aerobic environment, oxidation of reduced surface layers by diffusion alone is quite rapid, occurring within 6 to 12 hours (Germano 1983). Consequently, the detection of reduced mud clasts in an obviously aerobic setting suggests a recent origin. The size and shape of mud clasts, e.g., angular versus rounded, are also considered. Mud clasts may be moved about and broken by bottom currents and/or animals (macro- or meiofauna; Germano 1983). Over time, large angular clasts become small and rounded. Overall, the abundance, distribution, oxidation state, and angularity of mud clasts are used to make inferences about the recent pattern of seafloor disturbance in an area.

2.4.3.4 Sedimentary Methane

At extreme levels of organic-loading, pore-water sulphate is depleted, and methanogenesis occurs. The process of methanogenesis is detected by the appearance of methane bubbles in the sediment column. These gas-filled voids are readily discernable in REMOTS sediment-profile images because of their irregular, generally circular aspect and glassy texture (due to the reflection of the strobe off the gas). If present, the number and total areal coverage of all methane pockets are measured.

2.4.3.5 Measurement of Dredged Material and Cap Layers

The recognition of dredged material from REMOTS sediment-profile images is usually based on the presence of anomalous sedimentary materials within an area of ambient sediment. The ability to distinguish between ambient sediment and dredged or cap material demands that the survey extend well beyond the margins of a disposal site so that an accurate characterization of the ambient bottom is obtained. The distributional anomalies may be manifested in topographic roughness, differences in grain size, sorting, shell content, optical reflectance, fabric, or sediment compaction (i.e., camera prism penetration depth). Second-order anomalies may also provide information about the effects of dredged material on the benthos and benthic processes such as bioturbation (see following sections).

2.4.3.6 Boundary Roughness

Small-scale surface boundary roughness (i.e., surface relief) is measured from an image with the computer image analysis system. This vertical measurement is from the highest point at the sediment-water interface to the lowest point. This measurement of vertical relief is made within a horizontal distance of 15 cm (the total width of the optical window). Because the optical window is 20 cm high, the greatest possible roughness value is 20 cm. The source of the roughness is described if known. In most cases this is either biogenic (mounds and depressions

formed by bioturbation or foraging activity) or relief formed by physical processes (ripples, scour depressions, rip-ups, mud clasts, etc.).

2.4.3.7 Optical Prism Penetration Depth

The optical prism of the REMOTS sediment-profile camera penetrates the bottom under a static driving force imparted by its weight. The penetration depth into the bottom depends on the force exerted by the optical prism and the bearing strength of the sediment. If the weight of the camera prism is held constant, the change in penetration depth over a surveyed region will reflect horizontal variability in geotechnical properties of the seafloor. In this sense, the camera prism acts as a static-load penetrometer. The depth of penetration of the optical prism into the bottom can be a useful parameter, because dredged and capped materials often have different shear strengths and bearing capacities.

2.4.3.8 Infaunal Successional Stage

Determination of the infaunal successional stage applies only to soft-bottom habitats, where the REMOTS camera is able to penetrate into the sediment. In hard bottom environments (i.e., rocky substrates), camera penetration is prevented and the standard suite of REMOTS measurements cannot be made. In such instances, the infaunal successional stage is considered to be "indeterminate." Hard bottom areas can support abundant and diverse epibenthic communities and therefore may represent habitat which is biologically productive or otherwise is of value as refuge or living space for organisms. However, the value of hard bottom habitats is not reflected in the REMOTS successional stage designation.

The mapping of infaunal successional stages is based on the theory that organism-sediment interactions in marine soft-bottom habitats follow a predictable sequence after a major seafloor perturbation (e.g., passage of a storm, disturbance by bottom trawlers, dredged material deposition, hypoxia). The theory states that primary succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance. These invertebrates interact with sediment in specific ways. Because functional types are the biological units of interest, our definition does not demand a sequential appearance of particular invertebrate species or genera" (Rhoads and Boyer 1982). This theory is formally developed in Rhoads and Germano (1982) and Rhoads and Boyer (1982).

Benthic disturbance can result from natural processes, such as seafloor erosion, changes in seafloor chemistry, and predator foraging, as well as from human activities like dredged material or sewage sludge disposal, thermal effluent from power plants, bottom trawling, pollution from industrial discharge, and excessive organic loading. Evaluation of successional stages involves deducing dynamics from structure, a technique pioneered by R. G. Johnson (1972) for marine soft-bottom habitats. The application of this approach to benthic monitoring requires *in situ* measurements of salient structural features of organism-sediment relationships as imaged through REMOTS technology.

Pioneering assemblages (Stage I assemblages) usually consist of dense aggregations of near-surface living, tube-dwelling polychaetes (Figure 2.4-3); alternately, opportunistic bivalves may colonize in dense aggregations after a disturbance (Rhoads and Germano 1982, Santos and Simon 1980a). These functional types are usually associated with a shallow redox boundary;

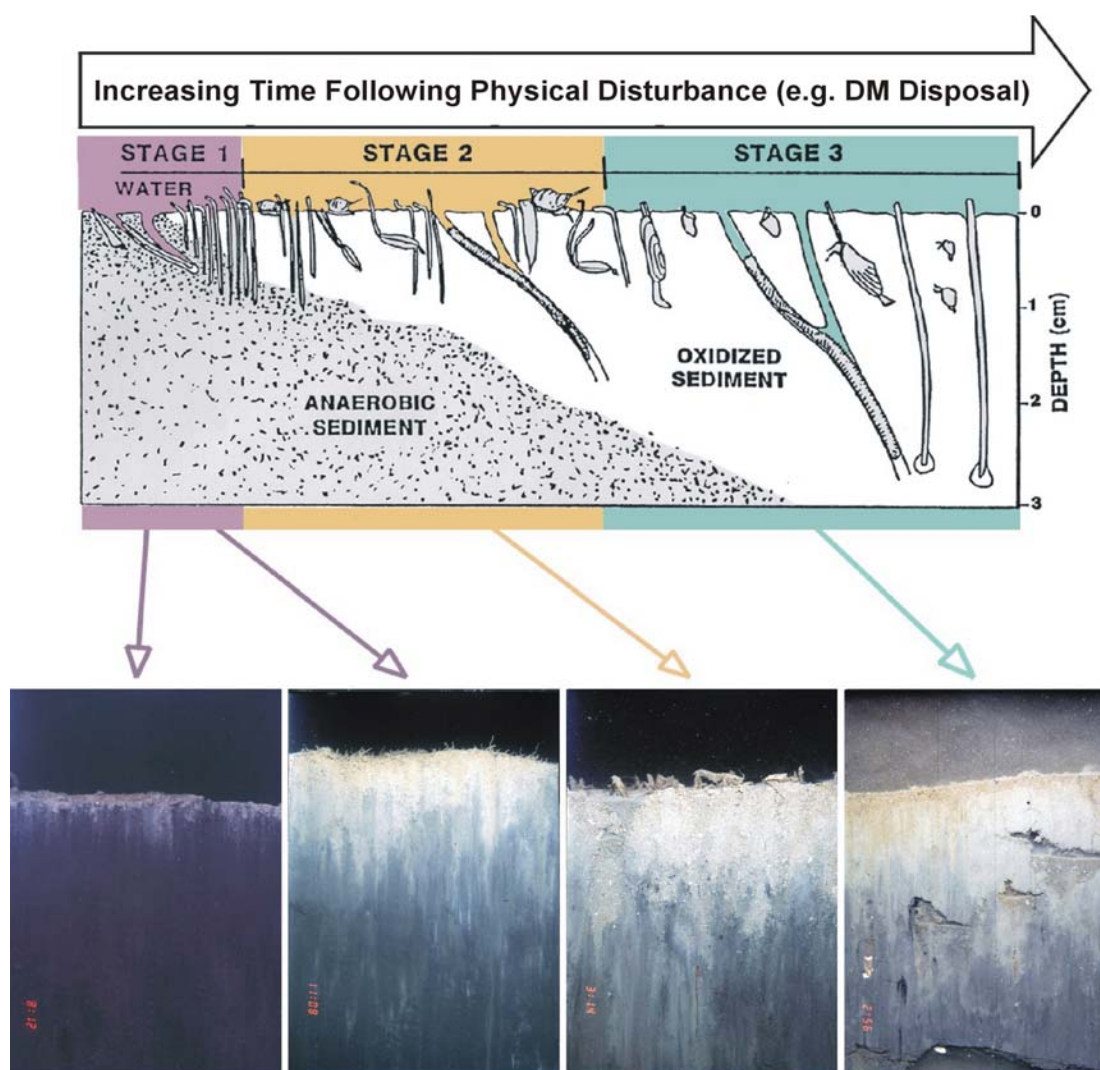


Figure 2.4-3. The drawing at the top illustrates the development of infaunal successional stages over time following a physical disturbance. The REMOTS images below the drawing provide examples of the different successional stages. Image A shows highly reduced sediment with a very shallow redox layer (contrast between light colored surface sediments and dark underlying sediments) and little evidence of infauna. Numerous small polychaete tubes are visible at the sediment surface in image B (Stage I), and the redox depth is deeper than in image A. A mixture of polychaete and amphipod tubes occurs at the sediment surface in image C (Stage II). Image D shows numerous burrow openings and feeding pockets (voids) at depth within the sediment; these are evidence of deposit-feeding, Stage III infauna. Note the RPD is relatively deep in this image, as bioturbation by the Stage III organisms has resulted in increased sediment aeration, causing the redox horizon to be located several centimeters below the sediment-water interface.

and bioturbation depths are shallow, particularly in the earliest stages of colonization (Figure 2.4-3). In the absence of further disturbance, these early successional assemblages are eventually replaced by infaunal deposit feeders; the start of this "infaunalization" process is designated arbitrarily as Stage II. Typical Stage II species are shallow dwelling bivalves or, as is common in New England waters, tubicolous amphipods. In studies of hypoxia-induced benthic defaunation events in Tampa Bay, Florida, Ampeliscid amphipods appeared as the second temporal dominant in two of the four recolonization cycles (Santos and Simon 1980a, 1980b).

Stage III taxa, in turn, represent high-order successional stages typically found in low-disturbance regimes. These invertebrates are infaunal, and many feed at depth in a head-down orientation. The localized feeding activity results in distinctive excavations called feeding voids (Figure 2.4-3). Diagnostic features of these feeding structures include a generally semicircular shape with a flat bottom and arched roof, and a distinct granulometric change in the sediment particles overlying the floor of the structure. This granulometric change is caused by the accumulation of coarse particles that are rejected by the animals feeding selectively on fine-grained material. Other subsurface structures, such as burrows or methane gas bubbles, do not exhibit these characteristics and therefore are quite distinguishable from these distinctive feeding structures. The bioturbational activities of these deposit-feeders are responsible for aerating the sediment. In the retrograde transition of Stage III to Stage I, it is sometimes possible to recognize the presence of relict (i.e., collapsed and inactive) feeding voids.

The end-member stages (Stages I and III) are easily recognized in REMOTS images by the presence of dense assemblages of near-surface polychaetes (Stage I) or the presence of subsurface feeding voids (Stage III; Figure 2.4-3). The presence of tubicolous amphipods at the sediment surface is indicative of Stage II. It is possible for Stage I polychaetes or Stage II tubicolous amphipods to be present at the sediment surface, while at the same time, Stage III organisms are present at depth within the sediment. In such instances, where two types of assemblages are visible in a REMOTS image, the image is designated as having either a Stage I on Stage III (I–III) or Stage II on Stage III (II–III) successional stage. Additional information on REMOTS image interpretation can be found in Rhoads and Germano (1982, 1986).

2.4.3.9 Apparent RPD Depth

Aerobic near-surface marine sediments typically have higher reflectance values relative to underlying anoxic sediments. Sand also has higher optical reflectance than mud. These differences in optical reflectance are readily apparent in REMOTS sediment-profile images; the oxidized surface sediment contains particles coated with ferric hydroxide (an olive color when associated with particles), while reduced and muddy sediments below this oxygenated layer are darker, generally gray to black. The boundary between the colored ferric hydroxide surface sediment and underlying gray to black sediment is called the apparent redox potential discontinuity (RPD).

The depth of the apparent RPD in the sediment column is an important time-integrator of dissolved oxygen conditions within sediment pore waters. In the absence of bioturbating organisms, this high reflectance layer (in muds) will typically reach a thickness of 2 mm (Rhoads 1974). This depth is related to the supply rate of molecular oxygen by diffusion into the bottom

and the consumption of that oxygen by the sediment and associated microflora. In sediments that have very high sediment-oxygen demand, the sediment may lack a high reflectance layer even when the overlying water column is aerobic.

In the presence of bioturbating macrofauna, the thickness of the high reflectance layer may be several centimeters. The relationship between the thickness of this high reflectance layer and the presence or absence of free molecular oxygen in the associated pore waters must be made with caution. The boundary (or horizon) which separates the positive Eh region (oxidized) from the underlying negative Eh region (reduced) can only be determined accurately with microelectrodes. For this reason, we describe the optical reflectance boundary, as imaged, as the "apparent" RPD, and it is mapped as a mean value.

The depression of the apparent RPD within the sediment is relatively slow in organic-rich muds (on the order of 200 to 300 micrometers per day); therefore, this parameter has a long time constant (Germano and Rhoads 1984). The rebound in the apparent RPD is also slow (Germano 1983). Measurable changes in the apparent RPD depth using the REMOTS sediment-profile image optical technique can be detected over periods of one or two months. This parameter is used effectively to document changes (or gradients), which develop over a seasonal or yearly cycle related to water temperature effects on bioturbation rates, seasonal hypoxia, sediment oxygen demand, and infaunal recruitment. In sediment-profile surveys of ocean disposal sites sampled seasonally or on an annual basis throughout the New England region performed under the DAMOS (Disposal Area Monitoring System) Program for the USACE, New England Division, SAIC repeatedly has documented a drastic reduction in apparent RPD depths at disposal sites immediately after dredged material disposal, followed by a progressive postdisposal apparent RPD deepening (barring further physical disturbance). Consequently, time-series RPD measurements can be a critical diagnostic element in monitoring the degree of recolonization in an area by the ambient benthos.

The depth of the mean apparent RPD also can be affected by local erosion. The peaks of disposal mounds commonly are scoured by divergent flow over the mound. This can result in washing away of fines, development of shell or gravel lag deposits, and very thin apparent RPD depths. During storm periods, erosion may completely remove any evidence of the apparent RPD (Fredette et al. 1988).

Another important characteristic of the apparent RPD is the contrast in reflectance values at this boundary. This contrast is related to the interactions among the degree of organic-loading, bioturbational activity in the sediment, and the levels of bottom-water dissolved oxygen in an area. High inputs of labile organic material increase sediment oxygen demand and, subsequently, sulfate reduction rates (and the abundance of sulfide end-products). This results in more highly reduced (lower reflectance) sediments at depth and higher RPD contrasts. In a region of generally low RPD contrasts, images with high RPD contrasts indicate localized sites of relatively high past inputs of organic-rich material (e.g., organic or phytoplankton detritus, dredged material, sewage sludge, etc.).

2.4.3.10 Organism-Sediment Index (OSI)

The multi-parameter REMOTS Organism-Sediment Index (OSI) has been constructed to characterize benthic habitat quality. Benthic habitat quality is defined relative to two end-member standards. The lowest value is given to a seafloor environment that has low or no dissolved oxygen in the overlying bottom water, no apparent macrofaunal life, and methane gas present in the sediment (see Rhoads and Germano 1982 and 1986 for the REMOTS criteria for these conditions). The OSI for such a condition is -10 (highly disturbed or degraded benthic habitat quality). At the other end of the scale, an aerobic bottom with a deeply depressed RPD, evidence of a mature macrofaunal assemblage, and no apparent methane gas bubbles at depth will have an OSI value of +11 (undisturbed or non-degraded benthic habitat quality).

The OSI is a sum of the subset indices shown in Table 2.4-5. The OSI is calculated automatically by SAIC software after completion of all measurements from each REMOTS photographic negative. The index has proven to be an excellent parameter for mapping disturbance gradients in an area and documenting ecosystem recovery after disturbance (Germano and Rhoads 1984, Revelas et al. 1987, Valente et al. 1992).

The OSI may be subject to seasonal changes because the mean apparent RPD depths vary as a result of temperature-controlled changes of bioturbation rates and sediment oxygen demand. Furthermore, the successional status of a station may change over the course of a season related to recruitment and mortality patterns or the disturbance history of the bottom. The sub-annual change in successional status is generally limited to Stage I (polychaete-dominated) and Stage II (amphipod-dominated) seres. Stage III seres tend to be maintained over periods of several years unless they are eliminated by increasing organic loading, extended periods of hypoxia, or burial by thick layers of dredged material. The recovery of Stage III seres following abatement of such events may take several years (Rhoads and Germano 1982). Stations that have low or moderate OSI values (< +6) are indicative of recently disturbed areas and tend to have greater temporal and spatial variation in benthic habitat quality than stations with higher OSI values (> +6).

2.4.4 Sediment Plan View Photograph Acquisition

Plan view (i.e., “downward-looking” or horizontal sediment surface plane) photographs of approximately 0.3 m² of the seafloor surface were obtained in conjunction with the REMOTS sediment-profile images at each station (Figure 2.4-1). The photographs were acquired with a PhotoSea® 1000a 35-mm underwater camera and strobe light system attached to the REMOTS sediment-profile camera frame. The plan view images were acquired immediately prior to the landing of the REMOTS sediment-profile camera frame on the seafloor, providing an undisturbed record of the surface sediments before penetration of the REMOTS sediment-profile prism. When the camera frame was lifted above the sediments, the plan view camera system automatically cycled the film and recharged the strobe in preparation for the next image. In this manner, a corresponding plan view image was usually obtained along with each REMOTS sediment-profile image.

Table 2.4-5.
Calculation of REMOTS Organism-Sediment Index Value

A. CHOOSE ONE VALUE:	
<u>Mean RPD Depth</u>	<u>Index Value</u>
0.00 cm	0
> 0 - 0.75 cm	1
0.75 - 1.50 cm	2
1.51 - 2.25 cm	3
2.26 - 3.00 cm	4
3.01 - 3.75 cm	5
> 3.75 cm	6
B. CHOOSE ONE VALUE:	
<u>Successional Stage</u>	<u>Index Value</u>
Azoic	-4
Stage I	1
Stage I to II	2
Stage II	3
Stage II to III	4
Stage III	5
Stage I on III	5
Stage II on III	5
C. CHOOSE ONE OR BOTH IF APPROPRIATE:	
<u>Chemical Parameters</u>	<u>Index Value</u>
Methane Present	-2
No/Low Dissolved Oxygen**	-4
REMOTS ORGANISM-SEDIMENT INDEX =	Total of above subset indices (A+B+C)
RANGE: -10 - +11	

** Note: This is not based on a Winkler or polarographic electrode measurement. It is based on the imaged evidence of reduced, low reflectance (i.e., high oxygen demand) sediment at the sediment-water interface.

2.4.5 Sediment Plan View Image Analysis

The purpose of the plan view image analysis was to supplement the more detailed and comprehensive REMOTS characterization of the seafloor. Analysis of the plan view images included screening all the replicate images acquired at each station to select one representative image for analysis. Poor water clarity, lack of contrast or water shots taken prematurely due to the camera system trigger sensitivity (sediment surface not within the focal length of the system when activated) eliminated some of the images from further consideration.

The plan view image analysis consisted of qualitative descriptions of key sediment characteristics (e.g., sediment type, bedforms and biological features) based on careful scrutiny of each chosen replicate image. Sediment descriptions were based on visual observations and therefore only the obvious presence of boulders, cobble, rock, gravel, sand and/or fines (clay and silt) were noted. Bedforms were described as being either rippled (i.e., presence of sand waves) or smooth (i.e., absence or very little evidence of sand waves) to provide an indication of physical processes (i.e., currents). Any evidence of epifaunal or infaunal organisms (i.e., fish, starfish, tubes, burrow openings, fecal mounds etc.) was also recorded.

2.5 Benthic Grab Sampling

2.5.1 Benthic Sample Collection

A single sediment grab sample was obtained for benthic community analysis at 15 of the 70 REMOTS stations over the Red Clay Area, as well as at 5 of the SADMA stations and at 3 of the 10 stations in the South Reference Area (Figure 2.4-1). The grab sample was collected at each station using a stainless steel, 0.04 m² Young-modified van Veen grab sampler having a maximum penetration depth of 12 cm (Figure 2.5-1). Upon arrival at the target station, the grab sampler was set in an open position and lowered to the seafloor on a stainless steel winch wire. Upon reaching the bottom, the device was retrieved, causing the bucket to close and retain a surface sediment sample. The grab sampler then was raised on the winch wire and placed on a stand secured to the deck of the survey vessel.

After retrieving the grab sampler, the sediment sample was determined to be acceptable or not. An acceptable grab was characterized as having relatively level, intact sediment over the entire area of the grab, and generally a sediment depth at the center of at least 7 cm. Grabs showing disturbance of the sediment surface or those containing an insufficient volume of sediment were determined to be unacceptable and rejected, resulting in re-deployment of the sampler at the station until an acceptable sample was obtained. The time of collection and geographic position of the sample were recorded both in the field logbook and by the navigation system.

Immediately following retrieval, a small subsample of surface sediment was scooped out of each acceptable grab and placed in a plastic bag for subsequent grain size analysis (Figure 2.5-1). The remaining sediment in the grab was transferred to a sieve having a 0.5 mm mesh size. During the sieving process, the sieve was placed on a sieve table, and a gentle flow of water was washed over the sample (Figure 2.5-2). Extreme care was taken to ensure that no sample was lost over the side of the sieve while agitating or washing the sample. The organisms and material (e.g., shells, wood, rock fragments, etc.) retained on the screen were placed into a labeled 1-L wide-mouth plastic



Figure 2.5-1. Photographs showing retrieval of the Van Veen grab sampler (left) and removal of a small subsample for grain size analysis (center and right)



Figure 2.5-2. Photographs showing red clay in the sieve prior to sieving (left), the sieving operation (center), and a sample of red clay near the completion of sieving (right)

container. The sample was then preserved using a 6% buffered formalin solution with Rose Bengal added to stain the organisms. Once the cap was secured, the contents were mixed by inverting the container several times. All samples were delivered by overnight mail to Barry A. Vittor and Associates, Inc. (BVA) of Mobile, AL for detailed benthic analysis (sorting, enumeration and identification to Lowest Practicable Identification Level (LPIL)).

2.5.2 Benthic Sample Processing

At the BVA laboratory, each benthic sample was sorted with a dissecting microscope, and the preserved specimens identified and counted. Individual organisms were removed from each sample and placed in vials, then labeled by major taxonomic group. Taxonomists with a specialization within each major taxonomic group proceeded to identify the preserved organisms to the LPIL. Quality Assurance and Control procedures (QA/QC) associated with the benthic taxonomic analyses at BVA are described in the Quality Assurance Project Plan (SAIC 2002).

2.5.3 Data Analysis

The raw benthic community data received from the laboratory consisted of a standard species list showing the number of individuals of each taxon collected in the single grab sample at each station. Since the Van Veen grab sampled a 0.04 m² area of the bottom, the raw sample counts were multiplied by 25 to express abundance on a standard “per m²” basis. Analysis of the benthic community data included both univariate and multivariate statistical approaches to determine similarities and differences among the three stations groups (i.e., Red Clay stations, SADMA stations, and South Reference Area stations), as described in the following sections.

2.5.3.1 Univariate Statistics

A number of standard univariate statistics were used to summarize the benthic community data for the three station groups, including calculation of the average organism density (number of individuals per m²) per station, average number of taxa, and the percentage breakdown of abundance by taxa. Additional analyses were performed to calculate species richness, diversity, and evenness index values for each station (sample), using the PRIMER (Plymouth Routines in Multivariate Ecological Research) software package developed at the Plymouth Marine Laboratory, UK (Clarke and Warwick 1994).

Species richness was determined using Margalef’s index (d), which provides a measure of the number of species (S) present for a given number of individuals (N) according to the following equation:

$$d = (S-1)/\log_2 N$$

Diversity was calculated using the Shannon-Weiner (H') index:

$$H' = -\sum_i p_i (\log_e p_i),$$

where p_i is the proportion of the total count arising from the i th species.

Equitability, the evenness of the species distribution, was determined using Pielou's evenness index (J'):

$$J' = H' (\text{observed}) / H' \text{ max,}$$

where H' max is the maximum possible diversity which would be achieved if all species were equally abundant = $\log_2 (S)$. All three indices were determined using the DIVERSE routine within the PRIMER software package.

2.5.3.2 Multivariate Statistics

The univariate statistics described in the previous section each provide a measure of a single community attribute (e.g., species richness, diversity, evenness). In contrast, multivariate statistical techniques involve looking at the benthic community structure as a whole when trying to discern spatial patterns or when comparing among different samples (Clarke 1999). The term "benthic community structure" used herein refers to the concept of looking simultaneously at both the taxa that are present and their relative numbers when comparing different samples to each other.

Using the PRIMER software package, two independent but complimentary multivariate techniques were used to evaluate both the among-station and among-group patterns in overall benthic community structure: hierarchical clustering and non-metric multi-dimensional scaling (nMDS). Each of these techniques serves to classify the stations into groups having mutually-similar benthic community structure. As explained in more detail below, the techniques differ in the type of graphical display produced.

Clustering and nMDS are non-parametric methods that do not require the data to be transformed to meet underlying statistical assumptions. However, transformations do play the important role in these techniques of defining the balance between contributions from common versus rarer species in the measure of similarity among samples. In the present analysis, a decision was made to apply a square root transformation to the species abundance data in order to down-weight the contribution of the numerically dominant taxa while increasing the contribution of the rarer and/or less abundant taxa in assessing the degree of similarity among samples.

Prior to performing the clustering, the abundance values were square-root transformed, and a matrix was then constructed consisting of Bray-Curtis similarity index values (Bray and Curtis 1957) calculated between each possible pair of stations (i.e., pairwise comparisons). Hierarchical agglomerative clustering with group-average linking was then performed on this similarity matrix (Clarke 1993). Representation of the results was by means of a tree diagram or dendrogram, with the y-axis representing the full set of samples and the x-axis representing the Bray-Curtis similarity level at which two samples or groups are considered to have fused.

Non-metric multi-dimensional scaling (nMDS) attempts to provide an ordination, or "map," of the stations such that distances between stations on the map reflect corresponding similarities or dissimilarities in community structure. Stations that fall in close proximity to one another on the map have similar community structure, while those that are farther apart have dissimilar structure (e.g., few taxa in common or the same taxa at different levels of abundance). Like the cluster

analysis, nMDS ordination (Kruskal and Wish 1978) was performed on the matrix of Bray-Curtis similarity index values derived from the square root transformed abundance data (Clark and Green 1988; Clarke 1993). The two-dimensional nMDS plot provides a simple and compelling visual representation of the “closeness” of the benthic community structure (i.e., species composition and abundance) between any two samples or sample groups.

The ANOSIM (Analysis of Similarities) randomisation test within the PRIMER software package was used to test for statistical differences in overall benthic community structure among the three station groups (Red Clay stations, SADMA stations, and South Reference Area stations). The ANOSIM procedure is analogous to standard parametric Analysis of Variance (ANOVA) but is based on a non-parametric permutation procedure applied to the Bray-Curtis similarity matrix underlying the ordination of samples (see Clarke and Green 1988; Clarke 1993). This test involves calculation of a test statistic, R , which reflects the observed differences in Bray-Curtis similarities among station groups, contrasted with differences among replicates within station groups.

The ANOSIM procedure was used to provide a formal test of the null hypothesis of “no significant difference in overall benthic community structure among the three different areas represented by the three station groups” (i.e., Red Clay versus SADMA versus South Reference Area). The R -statistic serves to indicate the magnitude of the difference among the areas being tested and can range from 0 to 1. In general, $R > 0.75$ indicates strong separation (i.e., a big difference in overall benthic community structure), $0.75 > R > 0.25$ indicates varying degrees of overlap but generally different community structure, and $R < 0.25$ indicates little separation among areas. The ANOSIM procedure also calculates a significance level that corresponds to the alpha level (probability of Type I error) in traditional ANOVA.

Following the ANOSIM test for among-area differences, the program SIMPER in the PRIMER package was used to identify the taxa that were the “key discriminators” in contributing to significant differences in benthic community structure among areas.

2.6 Sediment Vibracoring

2.6.1 Sampling Design and Field Methods

The sediment coring survey was conducted aboard the NYD’s M/V *Gelberman* from August 4 to 8, 2002. An Ocean Surveys, Inc. Model 1500 vibracorer, with an internal diameter of 3.5 inches, was used to acquire the core samples. One core was collected at each of the following three REMOTS stations: stations 68 and 76 located in the Red Clay Area and Station 2 in the SADMA (Figure 2.4-1). When appropriate the vessel utilized a point anchoring system for core collection. Immediately following retrieval of the vibracoring device at each station, the core liner was removed from the barrel and carefully capped and taped to prevent loss of sediment and/or water. The cores were cut on the survey vessel into approximately 80 cm lengths, labeled and stored vertically in a refrigerated unit, and processed at the NYD’s Caven Point laboratory facility by SAIC technicians.

2.6.2 Core Processing

In the laboratory, each core was split, visually described, digitally photographed, and sampled for geotechnical and total organic carbon (TOC) analyses. All subsamples were kept refrigerated until shipped to the appropriate subcontracting laboratory in coolers with wet ice. Samples for sediment TOC analysis were shipped to Pace Analytical, St. Paul, Minnesota. Geotechnical analyses included water content, bulk density, grain size, specific gravity and shear strength. SAIC technicians conducted the shear strength analysis on site while the remainder of the geotechnical analyses were conducted on samples shipped to Applied Marine Science in League City, Texas.

2.6.2.1 Core Splitting

Each core liner was scored horizontally using an SAIC designed core splitter. The core splitter is designed to score the exterior of the core liner, leaving a thin layer of Lexane liner such that the bits cut the liner and not the sediment. The thin layer of remaining liner was then cut using a pre-cleaned utility knife, and a thin wire was used to split the sediment axially into two halves. The wire was drawn from the top of the core to the bottom. One half-section of the core was used for detailed visual description, digital imaging, and sediment TOC analysis sampling. The remaining core half was processed for geotechnical analyses.

2.6.2.2 Core Descriptions and Imaging

After splitting, each core was carefully examined and described in detail by SAIC personnel. Visual descriptions follow a standard SAIC modification of ASTM (American Standard Test Method) D2488 for the Description and Identification of Soils (Visual-Manual Procedure). Core descriptions were entered directly into an SAIC database and tracking system. The tracking program generated the Chain-of-Custody forms sent to the laboratories along with the subsamples. The split cores were photographed with an Olympus D500L digital camera mounted on a tripod equipped with lights. The focal distance was kept constant to easily join (mosaic) the individual images to form a continuous view of the core. The descriptions, images and sample intervals were combined within the database and used to generate a log for each core.

2.6.2.3 Core Subsampling

The sediment cores were subsampled for both geotechnical and TOC analyses beginning on August 7, 2002. Table 2.6-1 summarizes the type of analyses performed on each core retained by SAIC. All of the cores were visually described and imaged. Sediment analyses included measurements of water content, bulk density, grain size (with hydrometer), specific gravity, and TOC. Additionally, one shear strength measurement was obtained per core. The core subsamples were collected from discrete 6 cm intervals evenly spaced over the length of the core. The three samples for TOC analysis were collected from the same sample interval as the sediment for geotechnical analysis.

Table 2.6-1.
Analysis Summary for the Vibracores Collected
over the SADMA and Red Clay Area During the 2002 Survey

Station	Core	Visual Description	Geotechnical Analysis	TOC Analysis	Total Core Length (cm)	Latitude (N)	Longitude (W)
68	RC68	X	X	X	158	40.3923	73.8351
76	RC76	X	X	X	282	40.3920	73.8345
2	SA2	X	X		292	40.3940	73.8505

2.6.3 Laboratory Analyses of Core Subsamples

2.6.3.1 Grain Size

Grain size distributions of the sediment samples were determined in accordance with ASTM Method D422. Sieve sizes for sand fraction analyses included US standard sieve sizes 10, 20, 40, 60, 100, and 200, to provide coarse (1–0 phi), medium (2–1 phi), fine (3–2 phi), and very fine (4–3 phi) sand fractions, respectively. Clay and silt fractions were measured using a hydrometer (ASTM Method D422). Size classifications were based on the Wentworth (1922) scale (Table 2.4-3).

2.6.3.2 Bulk Density and Water Content

Assuming no void space due to air, the wet mass of sediment divided by the volume yields the bulk density. Bulk density for the cores was determined by pushing a cylinder of known volume into the sediment surface of the core half, leveling off each end, and then weighing it. Water content is defined as the weight of water divided by the dry weight of the sample, and is reported as a percentage. Mathematically, it is computed using the following formula:

$$\text{Water Content} = ((\text{wet weight} - \text{dry weight}) / \text{dry weight}) \times 100$$

It should be noted that in geotechnical analysis, this formulation may indicate water content values greater than 100%. For this analysis, the wet samples were weighed, dried at 110°C for 24 hours, and then reweighed according to the procedures outlined in ASTM Method D 2216. Because these samples were from the marine environment, when dried, the salt from the water was left behind, resulting in a higher dry weight (weight of solids) and consequently lower water content. Since geotechnical properties are generally based on sediments saturated with fresh water, the water contents obtained via the above formula were then normalized by an assumed salt content of 32 ppt (typical salinity value at the HARS), following ASTM procedures.

2.6.3.3 Specific Gravity

Specific gravity is defined as the ratio of the mass of a unit volume of material to the same volume of gas-free distilled water at a stated temperature (ASTM Method D 854), and is represented by the following formula:

$$G \text{ at } T_b = M_o / [M_o + (M_a - M_b)]$$

where:

G = specific gravity

M_o = mass of sample of oven-dry soil, g₁

M_a = mass of pycnometer filled with water at temperature T_b, g₁

M_b = mass of pycnometer filled with water and soil at temperature T_b, g₁

T_b = temperature of the contents of the pycnometer when mass M_b was determined, °C.

Specific gravity was measured at one sample interval per Red Clay and SADMA core, using ASTM D 854, Method A (procedure for oven dried test specimens).

2.6.3.4 Shear Strength

A laboratory vane was used to make direct measurements of the shear strength of the sediment within the cores. Vane size is determined by the softness of the material to be measured; the laboratory vane used for this material measured 12.7 X 12.7 mm. Shear strength measurements were conducted on one half of the core. A motorized vane was used to ensure consistent torque and more accurate results. Shear strength, a calculated value based on degree of spring deflection (inner) and degree of rotation of the vane (outer). Softer material requires a larger vane and soft spring, while firmer material requires a stiffer spring and smaller vane. The SAIC procedure for vane shear testing is based on ASTM D4648.

$$S = M/K$$

Where:

S= Shear strength in kN/m^2

K= constant for the vane size used

M= Torque in N m

Vane 12.7 X 12.7 mm; K= 0.004290

Calculating M: $M = C_s \theta_f$

Where:

M= is the applied torque (N mm)

C_s = is the calibration factor (N mm/degree) for the spring being used obtained from calibration data.

θ_f = is the reading indicated by the pointer on the inner scale after each test gives the relative angular deflection of the ends of the spring failure.

2.6.3.5 Total Organic Carbon (TOC) Analysis

TOC analysis was performed using EPA's SW-846 Method 9060 (USEPA 1997). In this method, organic carbon is measured using a carbonaceous analyzer that converts the organic carbon in a sample to carbon dioxide (CO_2) by either catalytic combustion or wet chemical oxidation. The CO_2 formed is then either measured directly by an infrared detector or converted to methane (CH_4) and measured by a flame ionization detector. The amount of CO_2 or CH_4 in a sample is directly proportional to the concentration of carbonaceous material in the sample. Results in this report are expressed on a dry weight basis.

3.0 RESULTS

3.1 Sediment Vibracoring

The cores collected at REMOTS Stations 68 and 76 were labeled RC68 and RC76, respectively. Annotated photographs (i.e., logs) of these two cores, as well as Core SA2 collected at SADMA Station 2, are provided in Appendix A. Both of the cores contained red clay over their entire length (i.e., depth of penetration); the total core length was 158 cm for core RC68 and 282 cm for core RC76 (Appendix A). Core RC76 contained a small band (15 cm) of dark greenish gray silty clay from a depth of 22 to 37 cm. This was the only substantial indication of any sediment type besides red clay in these two cores. The pocket of greenish gray silty clay is most likely the result of natural variability in the area in which the red clay was originally dredged. The surface of Core RC68 was described as red, sandy clay; all other sediment intervals were distinctly clay.

Core SA2 collected at SADMA REMOTS Station 2 was distinctly different from the red clay cores in both sediment color and type (Appendix A). The majority of Core SA2 was described as black and contained pockets of both sand as well as clay. Unlike the odorless red clay cores, SA2 had a distinct marine odor.

On average, clay was the dominant grain size fraction (69%) in the red clay cores (Table 3.1-1). The average silt fraction was 23%, indicating that the majority of the sample was fine-grained. The USCS symbol for the red clay was CH (fat clay). Core SA2 contained equal portions of clay and fine sand (both at 33%), while silt comprised 22% of the sediment (Table 3.1-1). Similar to the red clay cores, there was very little coarse-grained sediment present. Of the two samples analyzed from core SA2, one was a fat clay (CH) while the other was sand with clay (SC) based on the USCS classification.

The average water content for the red clay samples was 40% (corrected for 35 ppt salinity; Table 3.1-2). This water content value is typical for consolidated, cohesive fine-grained sediment types with high shear strength. The water content of Core SA2 was significantly higher at 78%, more typical of less cohesive sediments, as indicated by the lower shear strength (Table 3.1-2). Water content and bulk density are inversely proportional as illustrated in Figure 3.1-1. Values for both bulk density and water content were more consistent down core in the red clay cores than they were in the SADMA core. The variability noted in the SADMA samples is typical for dredged material. The average dry bulk density of the red clay was 1.8 g/cc, compared to 1.5 g/cc for Core SA2.

Only one sample was analyzed from each red clay core for specific gravity, however, the results from each core were very similar, with an average of 2.7 ± 0.01 (Table 3.1-2). Core SA2 had a similar specific gravity of 2.58. Shear strength was analyzed at the same sample interval as specific gravity and ranged from 32 kPa (core RC76) to 68 kPa (core RC68; Table 3.1-2). These are typical values for clay, which tends to be more cohesive than silt. The variability in the shear strength of the red clay may be the result of the dredging process and compaction upon placement at the disposal site. Core SA2 had a significantly lower shear strength of 14 kPa, presumably due to the nature of the sediment and the greater proportion of sand, coarse-grained sediment, and higher water content.

Table 3.1-1.
Summary of Physical Properties for the Red Clay and SADMA Cores

	Average	Standard Deviation	Minimum	Maximum	Sample Count
RED CLAY CORES					
Gravel (%)	1.20	2.68	0.00	6.00	5
Coarse Sand (%)	0.92	0.98	0.00	2.50	5
Medium Sand (%)	1.51	1.25	0.12	3.07	5
Fine Sand (%)	4.84	4.14	0.39	9.46	5
Silt (%)	22.59	5.76	14.99	29.50	5
Clay (%)	68.95	12.15	58.00	84.50	5
Passing No. 200 (%)	-	-	-	-	-
USCS Symbol(s)	CH				5
SADMA CORE					
Gravel (%)	1.22	1.73	0.00	2.44	2
Coarse Sand (%)	0.75	0.87	0.13	1.36	2
Medium Sand (%)	8.96	7.33	3.78	14.14	2
Fine Sand (%)	33.56	16.10	22.17	44.94	2
Silt (%)	22.27	9.41	15.61	28.92	2
Clay (%)	33.25	16.62	21.50	45.00	2
Passing No. 200 (%)	-	-	-	-	-
USCS Symbol(s)	CH, SC				2

Table 3.1-2.
Summary of Geotechnical Properties for the Red Clay and SADMA Cores

Sample ID Red Clay Cores	Water Content (%)*	Wet Unit Wt. (g/cm ³)	Dry Unit Wt. (g/cm ³)	Specific Gravity	Shear Strength (kPa)
RC68-10	76	1.61	0.94	-	-
RC68-40	46	1.78	1.24	2.77	-
RC68-70	39	1.87	1.36	-	68.5
RC68-100	39	1.86	1.36	2.78	
RC68-100 (dup)	40	1.88	1.07	2.78	
RC68-140	38	1.86	1.36	-	-
RC76-30	25	2.03	1.64	-	-
RC76-60	40	1.84	1.33	-	-
RC76-90	43	1.84	1.31	-	-
RC76-150	36	1.89	1.40	2.75	32.11
RC76-220	24	2.17	1.76	-	-
Average	40.55	1.88	1.34	2.77	50.31
St. Dev.	13.57	0.14	0.23	0.01	25.73
Min.	24	1.61	0.94	2.75	32.11
Max.	76	2.17	1.76	2.78	68.5
SADMA Core					
SA2-20	32	1.93	1.48	-	-
SA2-80	141	1.39	0.61	-	-
SA2-120	107	1.47	0.74	2.58	14.57
SA2-120 (dup)	104	1.47	0.75	-	-
SA2-200	31	1.90	1.47	-	-
SA2-240	52	1.75	1.17	-	-
Average	77.83	1.65	1.04	2.58	14.57
St. Dev.	45.80	0.24	0.39	-	-
Min.	31	1.39	0.61	2.58	-
Max.	141	1.93	1.48	2.58	-

*Water Content corrected for 32 ppt salinity

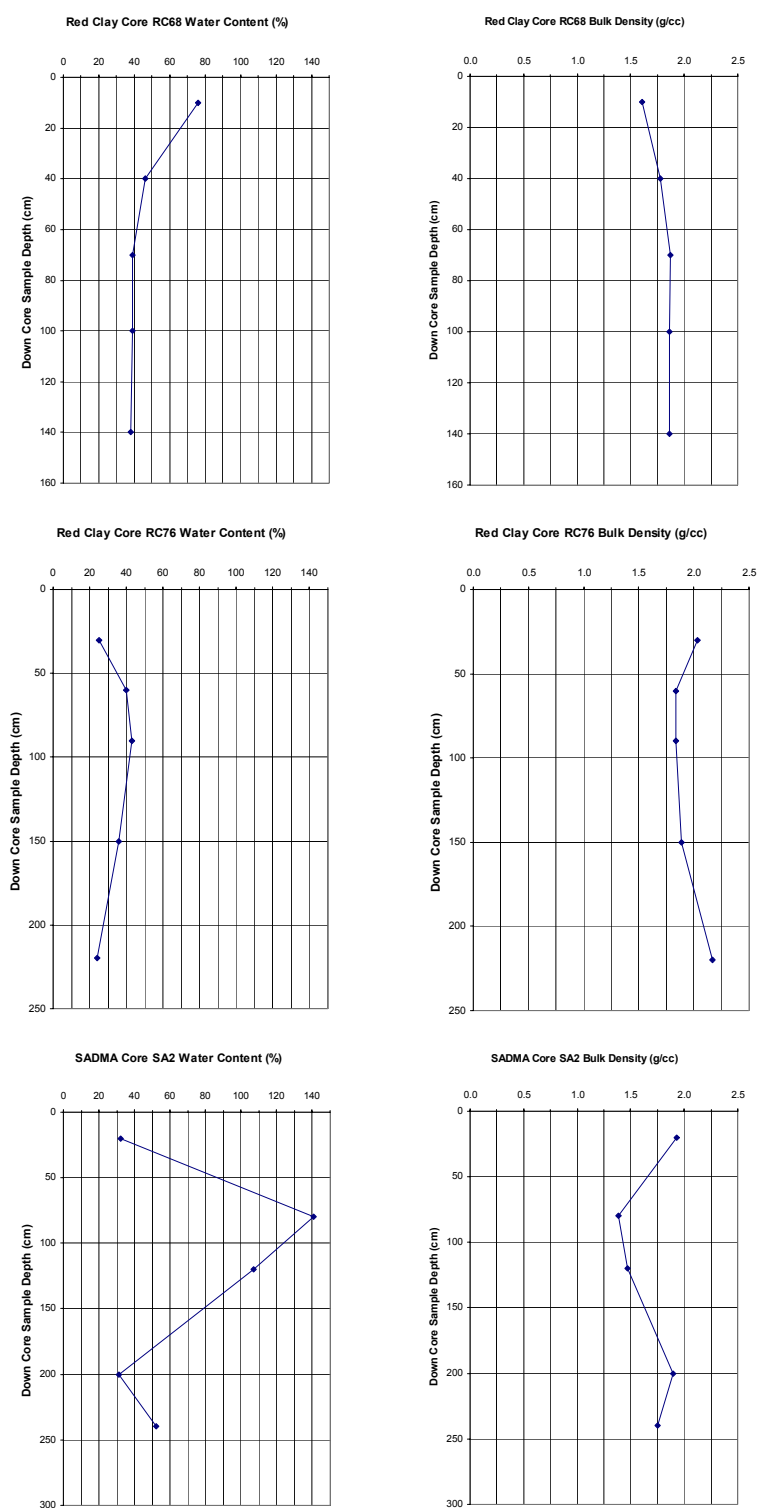


Figure 3.1-1. Vertical profiles of water content and bulk density of the three cores

Total organic carbon (TOC) was analyzed at three intervals in each of the red clay cores (Table 3.1-3). The concentration of TOC in all of the samples of red clay was less than 1%.

3.2 Side-Scan Sonar and Sub-bottom Profiling

The side-scan sonar mosaic revealed that the seafloor in the Red Clay Area was relatively featureless (Figure 3.2-1). In particular, there were no major changes or distinct patterns in acoustic reflectance associated with the three main areas of red clay disposal depicted in Figure 1.1-2. In addition, there was no indication of any heightened seafloor relief or roughness associated with the areas of red clay accumulation (Figure 3.2-1).

In the sub-bottom profiling record, a distinct but laterally discontinuous sub-bottom reflector was observed consistently at depth several meters below the seafloor surface (Figure 3.2-2). This reflector was assumed to be the bottom of the red clay deposit, leading to the conclusion that this deposit had a thickness ranging from 5 to 7 m in the area where the two vibracores were collected (Figure 3.2-2). Based on the disposal pattern shown in Figure 1.1-2, this is assumed to be the area where the thickest accumulations of red clay were located.

3.3 REMOTS Sediment-Profile Imaging and Plan View Photography

REMOTS sediment-profile and plan view imaging results for the June 2002 survey of the Red Clay Area, SADMA, and South Reference Area are presented below. Complete sets of REMOTS image analysis results for these three surveyed areas are provided in Appendix B; these results are summarized in Tables 3.3-1, 3.3-2 and 3.3-3.

3.3.1 Dredged Material Distribution and Physical Sediment Characteristics

Relic dredged material was observed in all of the REMOTS images obtained at the SADMA stations (Table 3.3-1; Figure 3.3-1). The dredged material was fine-grained, composed primarily of black, sulfide-rich silt-clay having a grain size major mode of >4 phi (Table 3.3-1; Figures 3.3-2 and 3.3-3). At all of the SADMA stations, the measured thickness of the relic dredged material layer exceeded the imaging depth of the sediment-profile camera (i.e., dredged material thickness shown with a “greater than” sign in Table 3.3-1).

The primary benthic habitat classification for the SADMA stations was very soft mud (habitat type UN.SF; Table 3.3-1; Figures 3.3-3 and 3.3-4). In four of the replicate images obtained at SADMA stations, a slightly higher apparent proportion of silt and fine sand resulted in benthic habitat type designations of UN.SS (soft mud with fine sand) and UN.SI (silty soft mud; Table 3.3-1). All the SADMA stations exhibited a distinct vertical stratigraphy in which a thin surface layer of fine sand was present over the black, fine-grained dredged material (Figures 3.3-3 and 3.3-5). This type of stratigraphy is commonly detected at the former Mud Dump Site and is presumed to be the result of ambient sand being transported by bottom currents over the deposited dredged material.

Table 3.1-3.
Total Organic Carbon (TOC) Concentrations in Core Subsamples
for the 2002 Monitoring Survey of the Red Clay Area

Core	Sample ID ¹	TOC (% dry wt.)	Material Type
RC68	RC68-40	0.71	red clay
	RC68-100	0.8	red clay
	RC68-140	1	red clay
RC76	RC76-60	0.91	red clay
	RC76-150	0.91	red clay
	RC76-220	1.1	red clay

¹indicates the depth in centimeters at which the samples were collected

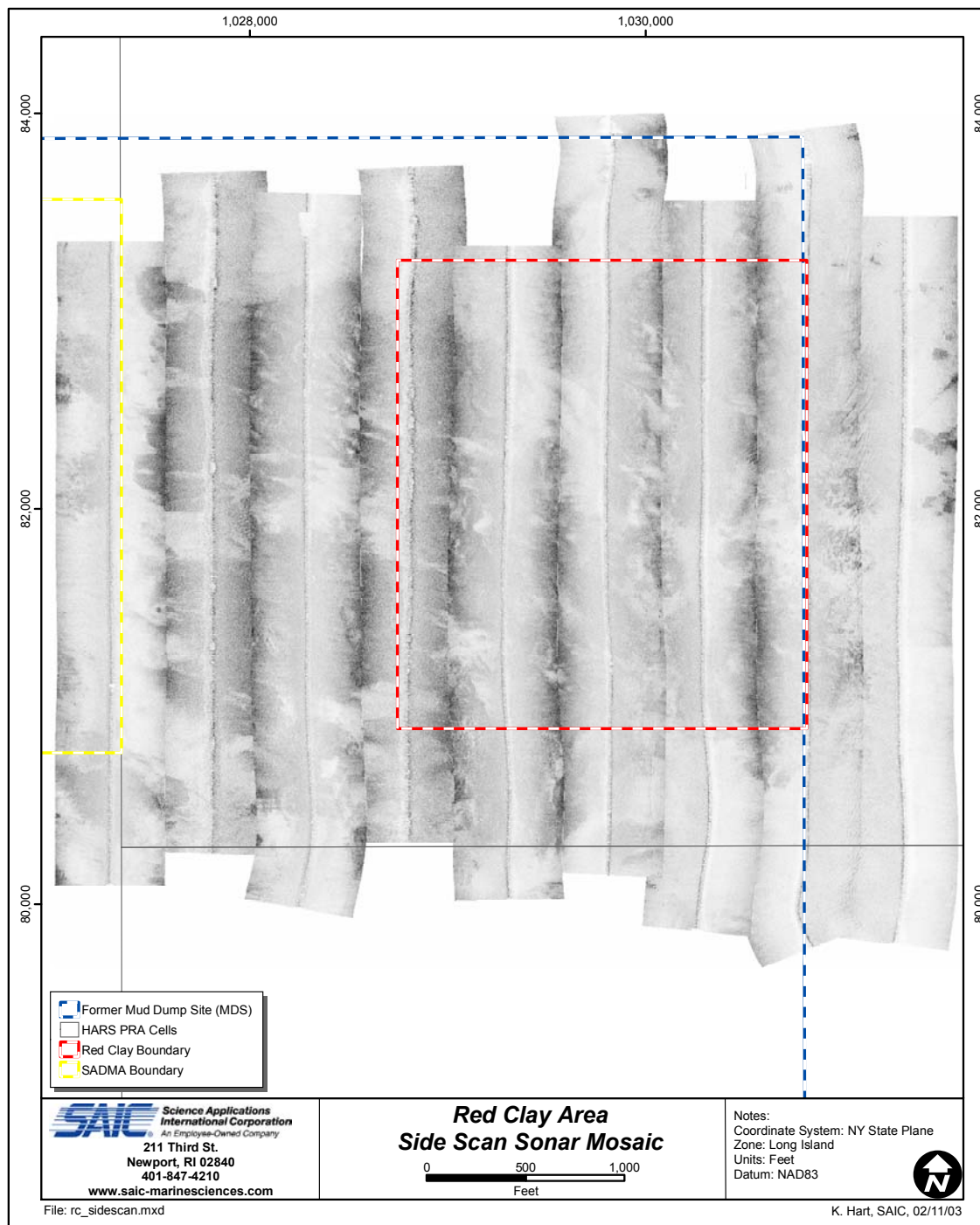


Figure 3.2-1. Side-scan sonar mosaic resulting from the summer 2002 survey over the Red Clay Area in the northeast corner of the former MDS. The dark areas that appear as a series of vertical lines are not seafloor features but artifacts resulting from splicing together of individual side-scan records (lanes) to create the mosaic.

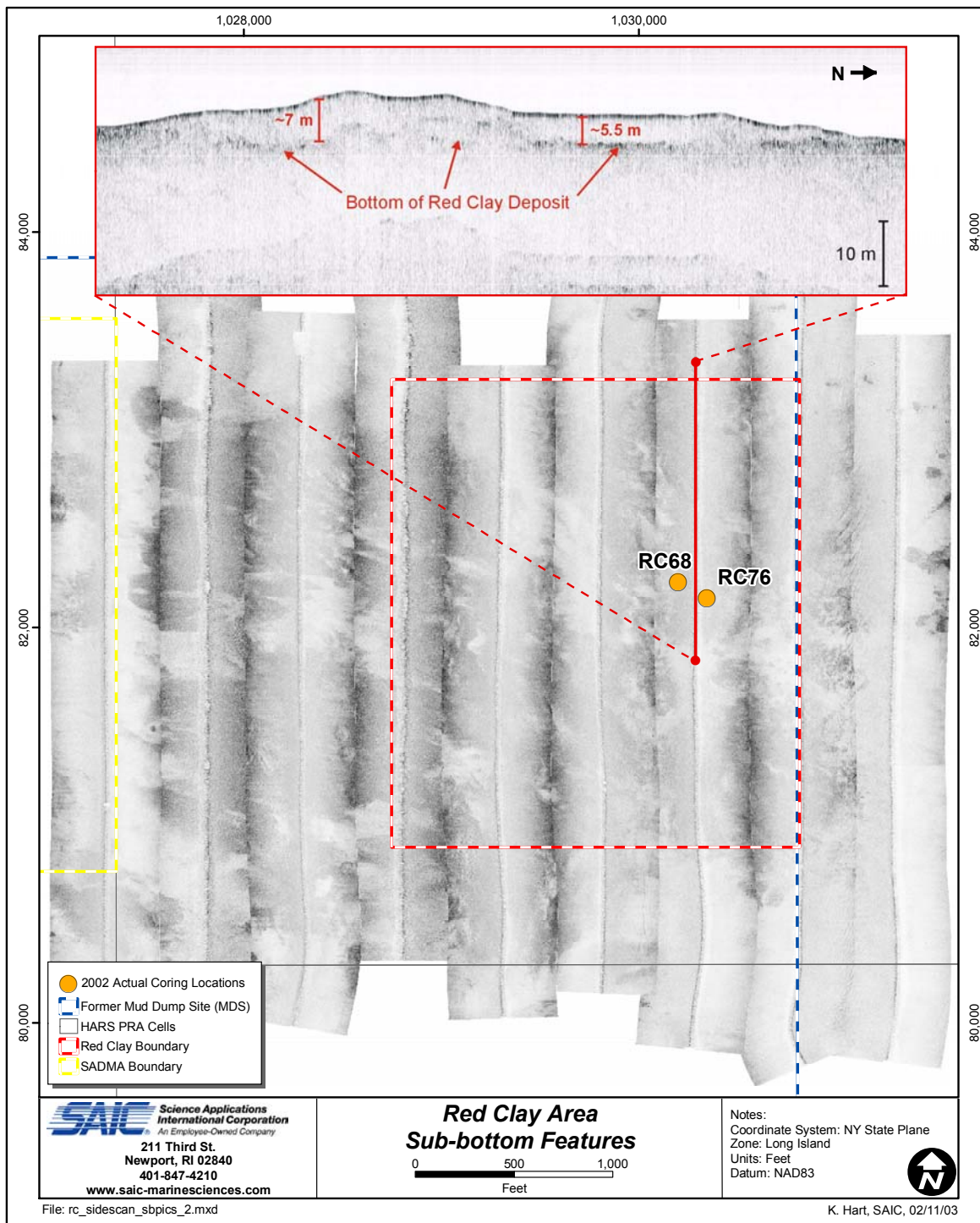


Figure 3.2-2. Side-scan sonar mosaic of the Red Clay Area showing the locations of the two stations where vibracores were collected, as well as the location of the sub-bottom profiling record that appears at the top.

Table 3.3-1.
Summary of REMOTS Sediment-Profile Imaging Results for the SADMA Stations, June 2002 Survey

Station	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Replicates With Dredged Material	Boundary Roughness Mean (cm)	Benthic Habitat (# replicates)	Successional Stages Present (# replicates)	RPD Mean (cm)	OSI Mean
1	> 4 phi (2)	13.2	> 13.2	2	1.1	UN.SF (2)	ST I (1), ST I on III (1)	1.1	5.0
2	> 4 phi (1), 3 to 2 phi (1)	10.5	> 10.5	2	0.9	UN.SF (1), UN.SS (1)	ST I (2)	3.0	5.0
3	> 4 phi (2)	12.0	> 12.0	2	1.0	UN.SF (1), UN.SI (1)	ST I (1), ST II (1)	1.3	4.5
14	> 4 phi (2)	12.3	> 12.3	2	1.9	UN.SF (2)	ST I (2)	1.9	4.0
15	> 4 phi (2)	13.1	> 13.1	2	0.9	UN.SF (2)	ST I (1), ST I on III (1)	1.7	5.5
16	> 4 phi (2)	12.1	> 12.1	2	0.9	UN.SI (2)	ST I (2)	1.8	4.0
AVG		12.2	> 12.2	2.0	1.1			1.8	4.7
MAX		13.2	> 13.2	2	1.9			3.0	5.5
MIN		10.5	> 10.5	0	0.9			1.1	4.0

Table 3.3-2.
Summary of REMOTS Sediment-Profile Imaging Results for the Red Clay Area Stations, June 2002 Survey

Station	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Replicates With Dredged Material	Boundary Roughness Mean (cm)	Benthic Habitat (# replicates)	Successional Stages Present (# replicates)	RPD Mean (cm)	OSI Mean
21	3 to 2 phi (2)	10.0	0.00	0	0.9	SA.F (2)	ST I (1), ST II (1)	5.0	7.5
22	> 4 phi (2)	8.3	> 8.3	2	1.6	UN.SF (2)	ST I on III (1), ST I to II (1)	2.2	7.0
23	> 4 phi (2)	6.7	> 6.7	2	1.9	UN.SI (2)	ST I (2)	2.5	5.0
24	> 4 phi (2)	6.0	> 6.0	2	1.0	UN.SI (2)	ST I (2)	2.5	5.0
25	> 4 phi (2)	10.0	> 10.0	2	0.4	UN.SI (2)	ST I (1), ST II (1)	3.2	6.5
26	> 4 phi (1), 4 to 3 phi (1)	4.9	> 4.9	2	2.2	UN.SI (1), UN.SS (1)	ST I (1), ST I on III (1)	2.7	7.0
27	> 4 phi (2)	10.2	> 10.2	2	0.7	UN.SI (2)	ST I on III (1), ST II (1)	2.9	8.0
28	3 to 2 phi (1), 4 to 3 phi (1)	6.7	> 6.7	2	1.8	UN.SS (2)	ST I (1), ST II (1)	2.7	6.0
29	2 to 1 phi (1), 3 to 2 phi (1)	8.9	> 8.9	2	1.0	UN.SS (2)	ST II (1), ST II on III (1)	3.8	9.5
30	> 4 phi (2)	7.0	> 7.0	2	1.1	UN.SI (2)	ST I on III (1), ST II (1)	2.0	8.0
31	> 4 phi (2)	6.1	> 6.1	2	1.0	UN.SI (2)	ST I (2)	2.1	4.5
32	> 4 phi (2)	7.3	> 7.3	2	1.3	UN.SF (1), UN.SI (1)	ST I (1), ST II (1)	4.1	9.0
33	> 4 phi (2)	10.4	> 10.4	2	0.4	UN.SF (1), UN.SI (1)	ST I (1), ST II (1)	2.6	7.0
34	> 4 phi (2)	7.1	> 7.1	2	1.1	UN.SI (2)	ST I (1), ST II (1)	INDET	INDET
35	> 4 phi (2)	8.8	> 8.8	2	3.2	UN.SF (2)	ST I (2)	4.4	6.5
36	> 4 phi (2)	3.6	> 3.6	2	1.1	UN.SF (1), UN.SI (1)	INDET (1), ST I (1)	INDET	INDET
37	> 4 phi (2)	5.6	> 5.6	2	0.8	UN.SF (2)	ST I (1), ST II (1)	1.9	5.0
38	> 4 phi (1), 3 to 2 phi (1)	7.0	> 7.0	2	1.5	UN.SI (1), UN.SS (1)	ST II (1), ST II on III (1)	2.1	7.5
39	4 to 3 phi (2)	6.0	> 6.0	2	1.0	UN.SS (2)	ST I (1), ST II (1)	2.0	6.0
40	> 4 phi (2)	6.7	> 6.7	2	0.7	UN.SF (2)	ST I (1), ST I on III (1)	2.4	5.0
41	> 4 phi (1), 4 to 3 phi (1)	3.3	> 3.3	2	1.4	UN.SI (1), UN.SS (1)	ST I (2)	2.3	5.0
42	> 4 phi (2)	6.4	> 6.4	2	0.8	UN.SF (1), UN.SI (1)	ST I (1), ST I on III (1)	2.3	9.0
43	> 4 phi (2)	4.9	> 4.9	2	1.0	UN.SI (2)	ST I (2)	3.3	6.0
44	> 4 phi (2)	11.9	> 11.9	2	1.2	UN.SF (1), UN.SI (1)	ST I on III (2)	2.4	8.5
45	> 4 phi (2)	10.3	> 10.3	2	0.9	UN.SF (1), UN.SI (1)	ST I (1), ST II on III (1)	1.9	8.0
46	> 4 phi (2)	6.3	> 6.3	2	1.8	UN.SI (2)	ST I on III (1), ST II (1)	2.7	8.0
47	> 4 phi (2)	8.3	> 8.3	2	1.8	UN.SF (1), UN.SI (1)	INDET (1), ST I (1)	INDET	INDET
48	> 4 phi (2)	4.0	> 4.0	2	0.6	UN.SF (1), UN.SI (1)	ST I (1), ST I to II (1)	INDET	INDET
49	> 4 phi (2)	5.9	> 5.9	2	1.4	UN.SI (2)	ST I (2)	3.0	5.5
50	> 4 phi (2)	4.5	2.51	1	1.0	UN.SI (2)	ST I (1), ST I on III (1)	2.5	9.0
51	> 4 phi (2)	5.2	> 5.2	2	1.8	UN.SI (2)	ST I (1), ST I to II (1)	2.0	4.0
52	> 4 phi (1), 4 to 3 phi (1)	2.5	> 2.5	2	0.9	UN.SI (2)	INDET (1), ST II (1)	1.9	6.0
53	4 to 3 phi (2)	5.5	> 5.5	2	0.6	UN.SS (2)	ST I (2)	3.3	6.0
54	> 4 phi (1), 4 to 3 phi (1)	4.0	> 4.0	2	1.1	UN.SI (2)	ST I (2)	2.0	4.0
55	> 4 phi (2)	10.5	> 10.5	2	1.8	UN.SF (2)	ST I (1), ST III (1)	2.7	9.0
56	> 4 phi (2)	6.9	> 6.9	2	1.0	UN.SI (2)	ST I (2)	3.5	6.0
57	> 4 phi (2)	10.1	> 10.1	2	0.7	UN.SF (1), UN.SI (1)	ST I (1), ST II (1)	2.3	5.5
58	> 4 phi (2)	4.9	> 4.9	2	1.1	UN.SI (2)	ST I (1), ST I on III (1)	2.3	7.0
59	> 4 phi (2)	10.6	> 10.6	2	0.6	UN.SI (2)	ST I (2)	3.0	6.0
60	> 4 phi (2)	7.2	> 7.2	2	1.1	UN.SI (2)	ST I (1), ST I on III (1)	3.1	7.5

Table 3.3-2. (continued)

Station	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number Of Replicates With Dredged Material	Boundary Roughness Mean (cm)	Benthic Habitat (# replicates)	Successional Stages Present (# replicates)	RPD Mean (cm)	OSI Mean
61	> 4 phi (2)	5.6	> 5.6	2	1.0	UN.SI (2)	ST I (1), ST I to II (1)	3.5	7.0
62	> 4 phi (2)	5.7	> 5.7	2	0.7	UN.SF (2)	ST I on III (2)	2.0	8.0
63	> 4 phi (2)	9.4	> 9.4	2	0.7	UN.SI (2)	ST I (1), ST II (1)	INDET	INDET
64	> 4 phi (2)	6.2	> 6.2	2	1.0	UN.SI (2)	ST I (1), ST II (1)	3.0	6.5
65	> 4 phi (2)	4.7	> 4.7	2	1.1	UN.SI (2)	ST I (1), ST I to II (1)	1.9	4.5
66	> 4 phi (1), 3 to 2 phi (1)	3.8	2.2	1	0.8	UN.SI (1), UN.SS (1)	ST I (2)	2.1	4.5
67	> 4 phi (1), 3 to 2 phi (1)	6.2	2.8	1	2.6	SA.F (1), UN.SI (1)	ST I on III (1), ST II (1)	4.0	9.0
68	> 4 phi (2)	12.1	> 12.1	2	0.7	UN.SF (2)	ST I (2)	INDET	INDET
69	> 4 phi (1), 0 to -1 phi (1)	2.2	> 2.2	2	0.8	HR (1), UN.SI (1)	INDET (1), ST I (1)	INDET	INDET
70	> 4 phi (2)	6.9	> 6.9	2	1.0	UN.SI (2)	ST I (1), ST I to II (1)	2.6	6.0
71	> 4 phi (2)	9.2	> 9.2	2	1.7	UN.SI (2)	ST II (2)	2.3	6.5
72	> 4 phi (2)	7.6	> 7.6	2	1.0	UN.SI (2)	ST II (1), ST II on III (1)	1.6	7.0
73	> 4 phi (1), 3 to 2 phi (1)	7.1	4.5	1	0.7	SA.F (1), UN.SI (1)	ST I (1), ST II (1)	3.9	7.0
74	> 4 phi (1), 4 to 3 phi (1)	3.7	> 3.7	2	1.0	UN.SS (2)	ST I (1), ST I to II (1)	2.0	4.5
75	> 4 phi (2)	4.2	> 4.2	2	0.9	UN.SI (2)	ST I (1), ST II (1)	2.5	6.0
76	> 4 phi (2)	11.8	> 11.8	2	0.9	UN.SF (2)	ST I (1), ST I on III (1)	1.6	8.0
77	> 4 phi (2)	6.2	> 6.2	2	0.9	UN.SI (2)	ST II (1), ST II on III (1)	1.8	7.0
78	> 4 phi (2)	6.6	> 6.6	2	1.5	UN.SI (2)	ST I (2)	2.4	5.0
79	> 4 phi (2)	14.2	> 14.2	2	0.9	UN.SF (2)	ST I (1), ST II on III (1)	2.0	6.0
80	> 4 phi (1), 4 to 3 phi (1)	5.9	> 5.9	2	1.3	UN.SF (1), UN.SS (1)	ST I on III (1), ST II (1)	1.2	6.0
81	> 4 phi (1), 4 to 3 phi (1)	10.6	> 10.6	2	0.6	UN.SI (1), UN.SS (1)	ST I (1), ST II (1)	2.7	6.0
82	> 4 phi (2)	7.8	> 7.8	2	1.5	UN.SI (2)	ST II (1), ST II on III (1)	2.1	7.5
83	> 4 phi (2)	11.7	> 11.7	2	0.9	UN.SF (2)	ST I (2)	2.2	4.5
84	> 4 phi (2)	12.3	> 12.3	2	0.8	UN.SI (2)	ST I on III (1), ST II (1)	2.3	7.5
85	> 4 phi (2)	8.8	> 8.8	2	0.7	UN.SI (2)	ST I (1), ST II (1)	2.0	5.0
86	> 4 phi (2)	11.0	> 11.0	2	0.8	UN.SF (1), UN.SI (1)	ST II (2)	1.9	6.0
87	> 4 phi (2)	8.0	> 8.0	2	1.1	UN.SF (1), UN.SI (1)	ST I (1), ST II (1)	2.0	5.0
88	> 4 phi (2)	7.8	> 7.8	2	1.9	UN.SF (2)	ST I (2)	2.8	5.0
89	> 4 phi (2)	10.8	> 10.8	2	1.4	UN.SI (2)	ST I (2)	0.9	3.0
90	> 4 phi (2)	12.1	> 12.1	2	0.5	UN.SI (2)	ST II (1), ST II on III (1)	2.8	8.5
AVG		7.4	> 7.2	1.9	1.1			2.5	6.5
MAX		14.2	> 14.2	2	3.2			5.0	9.5
MIN		2.2	0.0	0	0.4			0.9	3.0

Table 3.3-3.

Summary of REMOTS Sediment-Profile Imaging Results for the South Reference Area (SREF) Stations, June 2002 Survey

Station	Grain Size Major Mode (# replicates)	Camera Penetration Mean (cm)	Boundary Roughness Mean (cm)	Benthic Habitat (# replicates)	Successional Stages Present (# replicates)	RPD Mean (cm)	OSI Mean
SREF10	3 to 2 phi (2)	4.3	0.7	SA.F (2)	ST I (2)	> 4.3	7.0
SREF11	3 to 2 phi (2)	6.2	1.1	SA.F (2)	ST I (2)	3.7	6.0
SREF14	3 to 2 phi (2)	4.4	0.8	SA.F (2)	ST I (2)	> 4.4	7.0
SREF16	3 to 2 phi (2)	4.7	1.0	SA.F (2)	ST I (2)	2.9	5.5
SREF18	3 to 2 phi (2)	4.9	0.5	SA.F (2)	ST I (2)	> 4.9	7.0
SREF20	3 to 2 phi (1), 4 to 3 phi (1)	6.2	0.4	SA.F (2)	ST I (2)	4.3	6.0
SREF3	2 to 1 phi (2)	6.2	1.7	SA.M (2)	ST I (2)	> 6.2	7.0
SREF4	3 to 2 phi (2)	5.1	0.3	SA.F (2)	ST I (2)	> 5.1	6.5
SREF5	3 to 2 phi (2)	6.3	1.1	SA.F (2)	ST I (2)	> 6.3	7.0
SREF8	3 to 2 phi (2)	5.4	0.5	SA.F (2)	ST I (2)	3.2	5.5
AVG		5.4	0.8			4.5	6.5
MAX		6.3	1.7			> 6.3	7.0
MIN		4.3	0.3			2.9	5.5

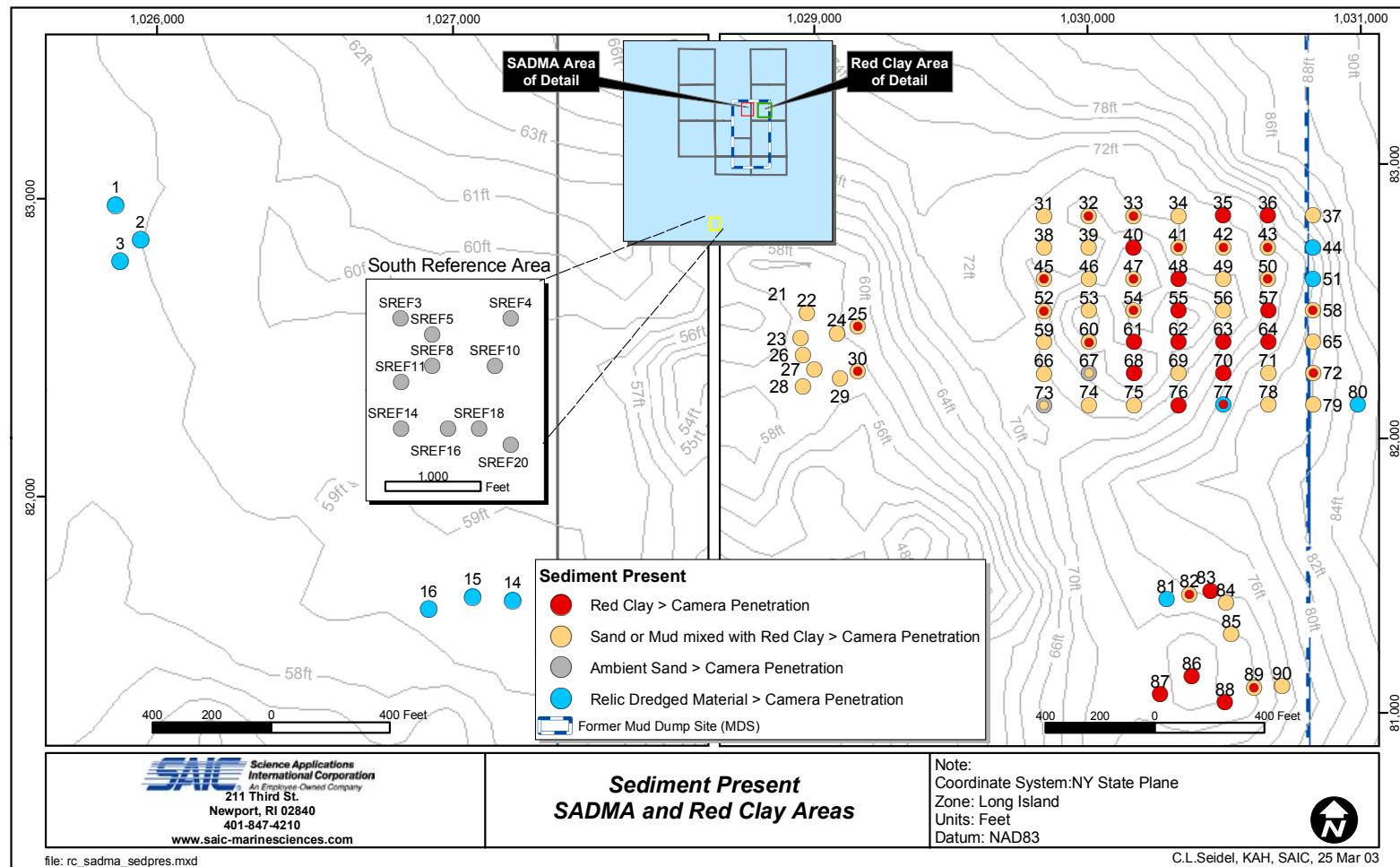


Figure 3.3-1. Map of sediment types observed in the REMOTS images at the SADMA, Red Clay, and South Reference Area stations. Two colors at a station indicate different results for each of the two replicate REMOTS images.

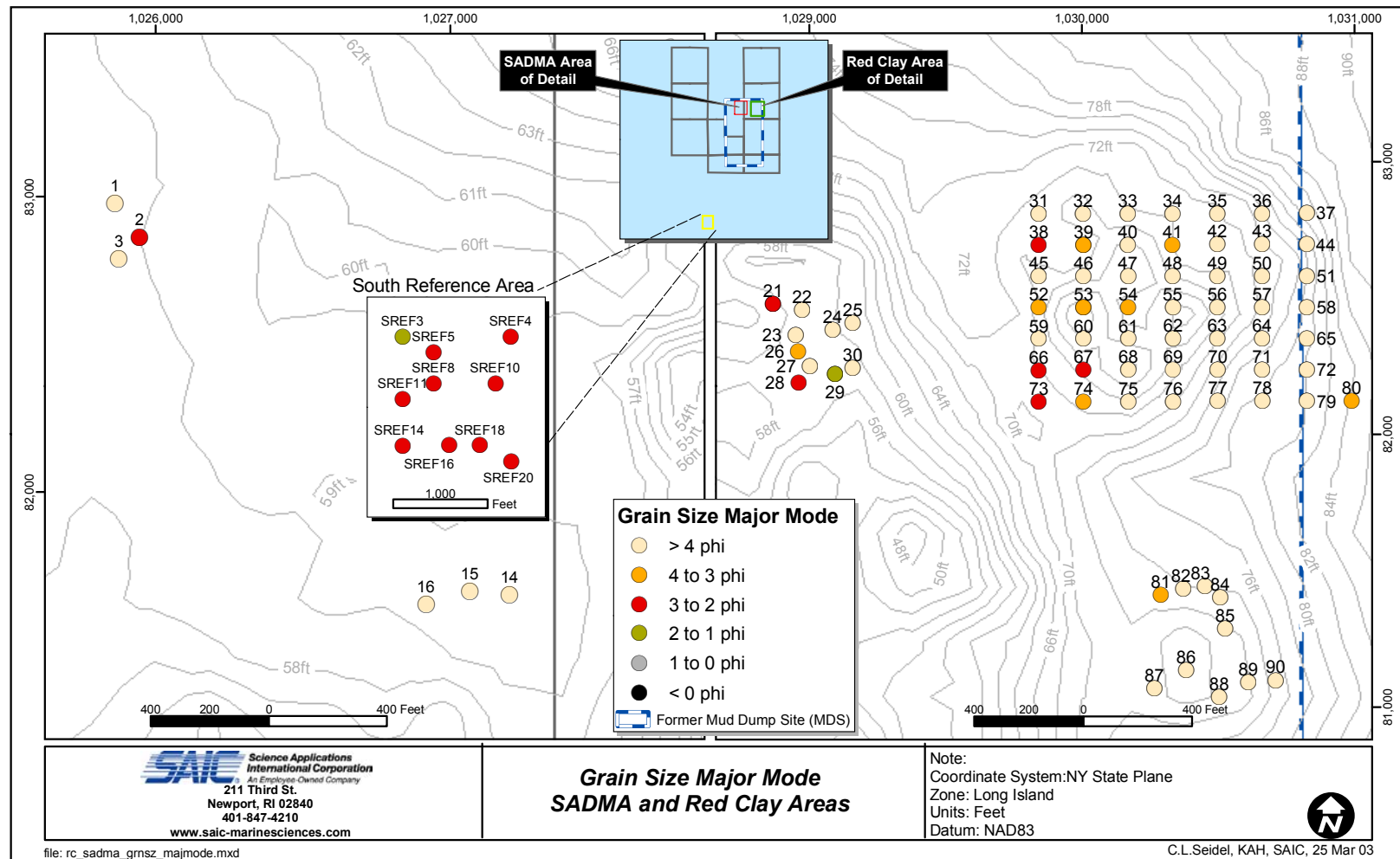


Figure 3.3-2. Map showing the grain size major mode (in phi units) of surface sediments at the SADMA, Red Clay, and South Reference Area stations

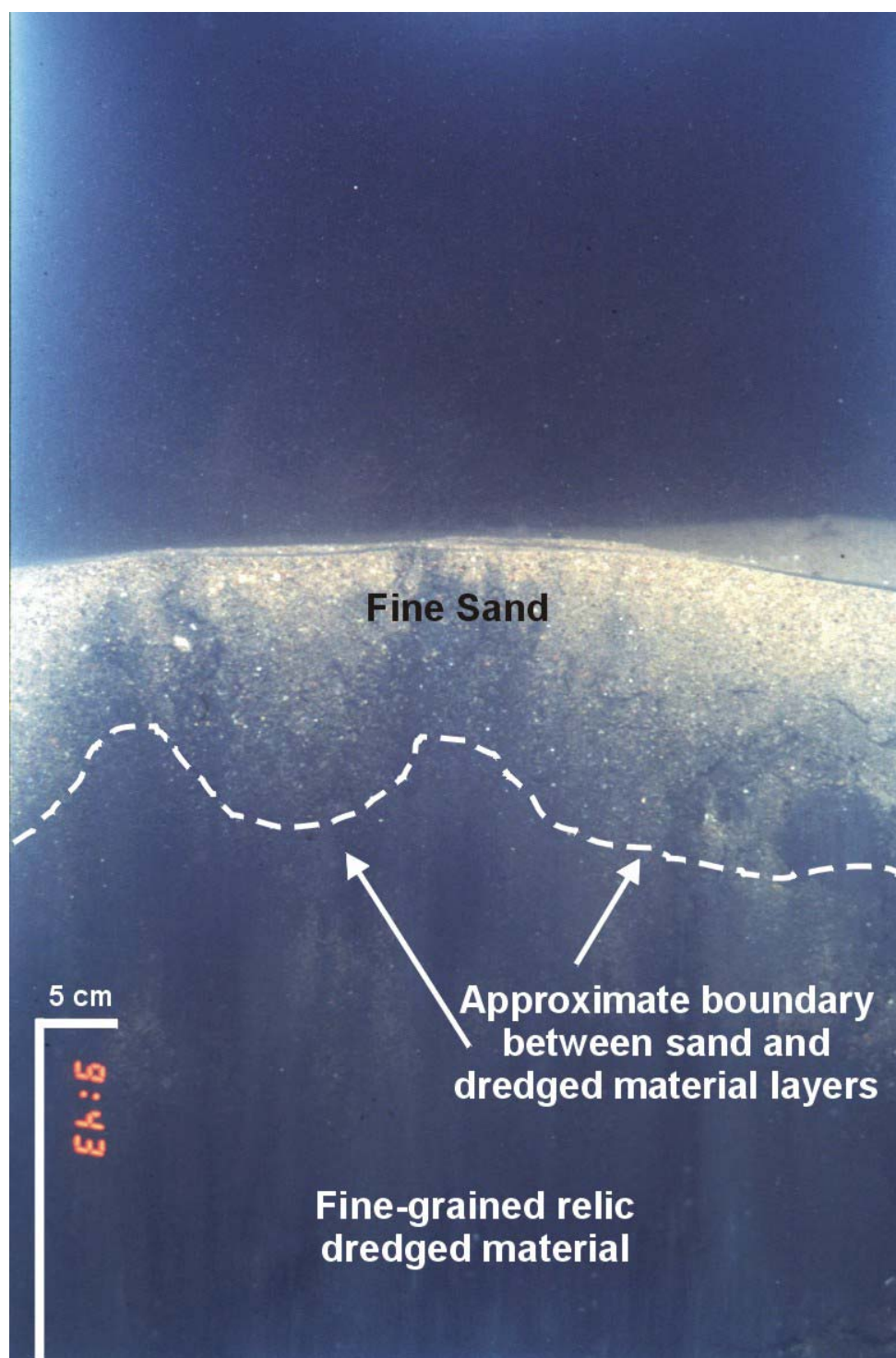


Figure 3.3-3. REMOTS image from SADMA Station 1 showing fine-grained, relic dredged material. The extreme blackness of the sediment at depth suggests a high inventory of sulfides. A thin veneer of light-colored, fine sand is present at the sediment-water interface, overlying the black dredged material. This is an example of habitat type UN.SF (unconsolidated, soft mud).

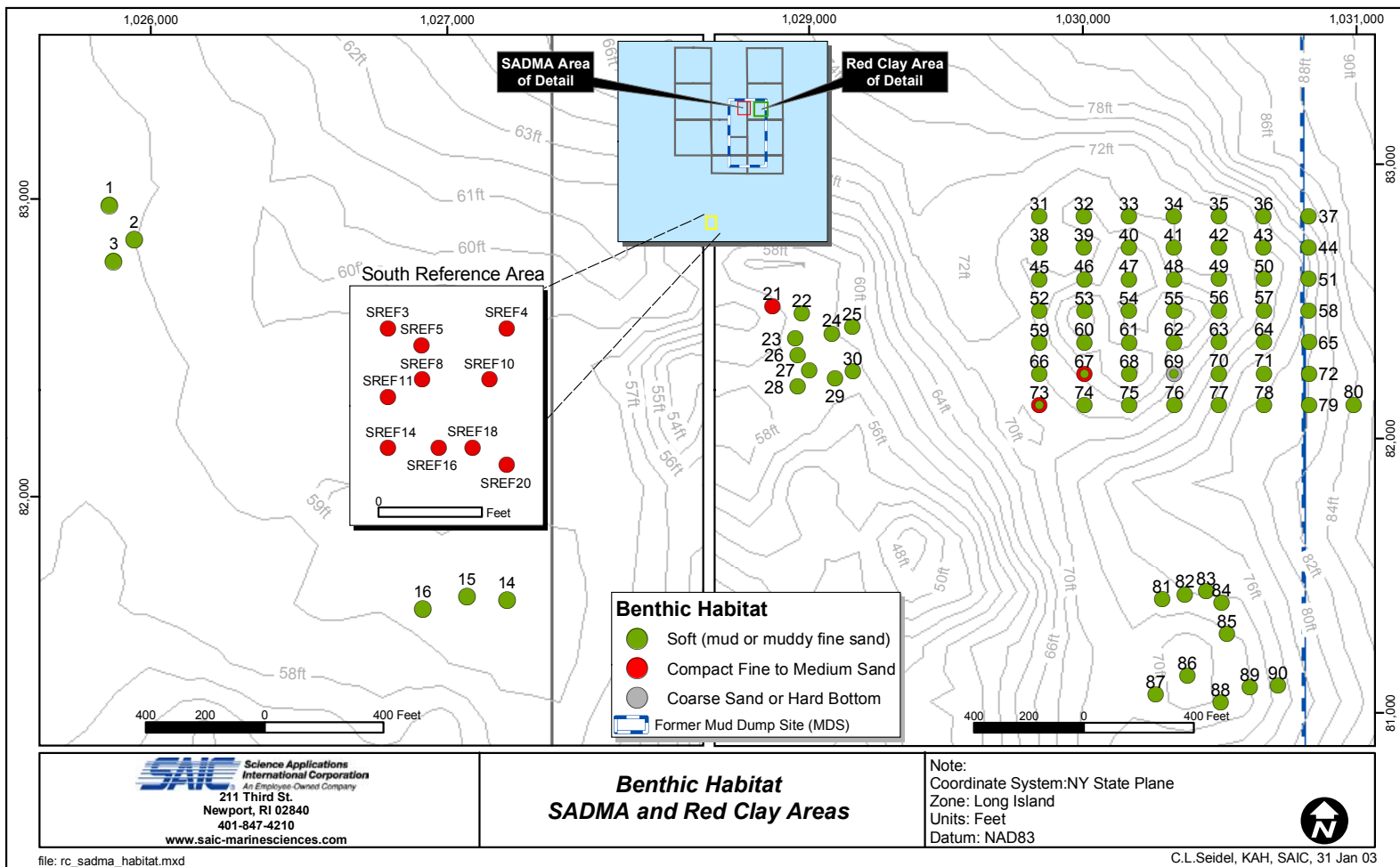


Figure 3.3-4. Map of benthic habitat types observed in the REMOTS images at the SADMA, Red Clay, and South Reference Area stations. Two colors at a station indicate different habitat types observed in each of the two replicate images.

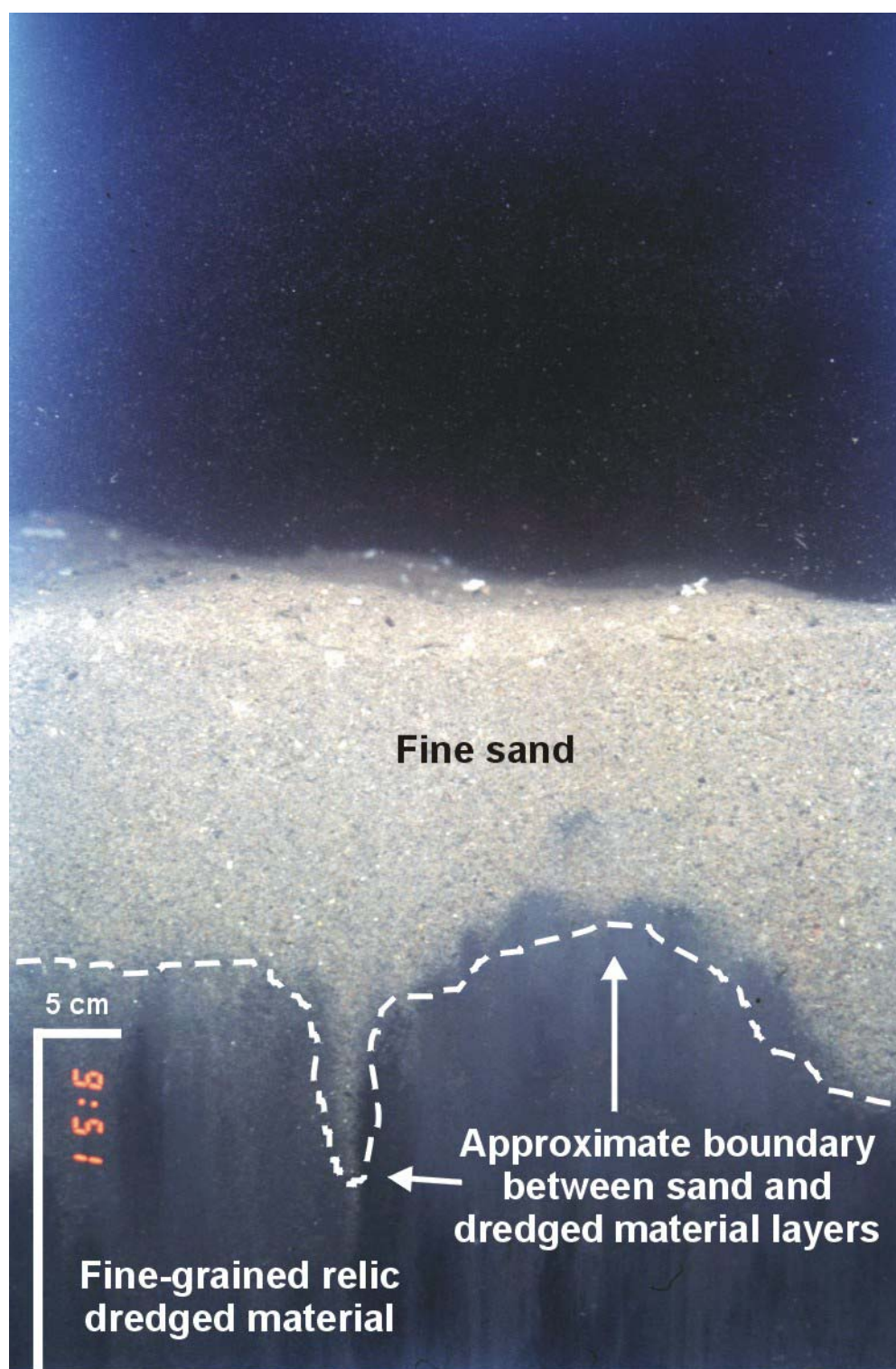


Figure 3.3-5. REMOTS image from SADMA Station 2 illustrating the distinct stratigraphy in which a surface layer of light-colored, well-sorted fine sand overlies black, fine-grained dredged material at depth.

The sediment comprising the surface of the red clay deposit had a variable appearance in the sediment-profile images. Cohesive red clay was observed at the majority of stations, but it often appeared to be mixed with a significant amount of pebbles, sand and/or silt (Figures 3.3-1 and 3.3-6, images A and B). At other stations, the red clay was more homogenous in appearance, with little or no sand or pebbles (Figure 3.3-6, image C). The measured thickness of the red clay exceeded the camera prism penetration (i.e., imaging) depth at the majority of stations (Table 3.3-2). Fine-grained relic dredged material was observed instead of red clay at five stations, including stations 44, 51 and 80 on the eastern side of the main red clay deposit (Figure 3.3-1). Ambient fine sand was observed instead of red clay at Stations 21, 67, and 73 (Figure 3.3-1).

The grain size major mode at stations located over the red clay deposit was predominately >4 phi (silt-clay; Table 3.3-2 and Figure 3.3-2). However, as indicated there was some variability in grain size major mode among stations within the Red Clay Area. A number of stations had significant amounts of very fine sand (4 to 3 phi) and fine sand (3 to 2 phi) mixed with the red clay. Medium sand (2 to 1 phi) was present at Station 29, while a number of stations displayed sandy silt or muddy fine sand (4 to 3 or 3 to 2 phi; Figure 3.3-2).

The primary benthic habitat classification at the Red Clay stations was silty, unconsolidated mud (habitat type UN.SI; Figure 3.3-4). Unconsolidated, fine-grained sediment with a high apparent proportion of fine sand (habitat type UN.SS), very soft mud (habitat type UN.SF), and very fine sand (habitat type SA.F) also was detected at a number of stations (Table 3.3-2 and Figure 3.3-4). Hard bottom conditions resulting from stiff, cohesive red clay clumps or rocks were present at Station 69 (grain size major mode of < 0 phi and benthic habitat HR; Figures 3.3-2 and 3.3-4).

The South Reference Area was dominated by well-sorted, ambient fine sand, with a grain size major mode of 3 to 2 phi (Table 3.3-3 and Figure 3.3-7). The predominant benthic habitat type at the South Reference Area stations was fine sand (SA.F), except for Station SREF 3 which had medium sand (SA.M; Figure 3.3-4). No relic dredged material was detected at the South Reference Area stations.

Average camera prism penetration depth measurements at the SADMA stations ranged from 10.5 cm at Station 2 to 13.2 cm at Station 1, with an overall average of 12.2 cm (Table 3.3-1 and Figure 3.3-8). These are moderately deep penetration values (possible range=1 to 20 cm) that reflect the relatively soft, fine-grained nature of the relic dredged material present in the SADMA. Average prism penetration measurements were lower at the Red Clay stations, ranging from 2.2 cm at Station 69 to 14.2 cm at Station 79 (Table 3.3-2 and Figure 3.3-8). The overall average of 7.4 cm for the Red Clay stations reflects the presence of more compact sediment and/or cohesive clay that tended to resist deeper penetration by the sediment-profile camera.

Mean camera prism penetration measurements at the South Reference Area ranged from 4.3 cm at Station SREF10 to 6.3 cm at Station SREF5 (Table 3.3-3). The overall average of 5.4 cm was lower than the values observed within both the SADMA and Red Clay Area and is due to the presence of relatively compact, ambient sand. Most of the higher penetration values at the South Reference Area were found in its northwest corner; the camera penetration was surprisingly high

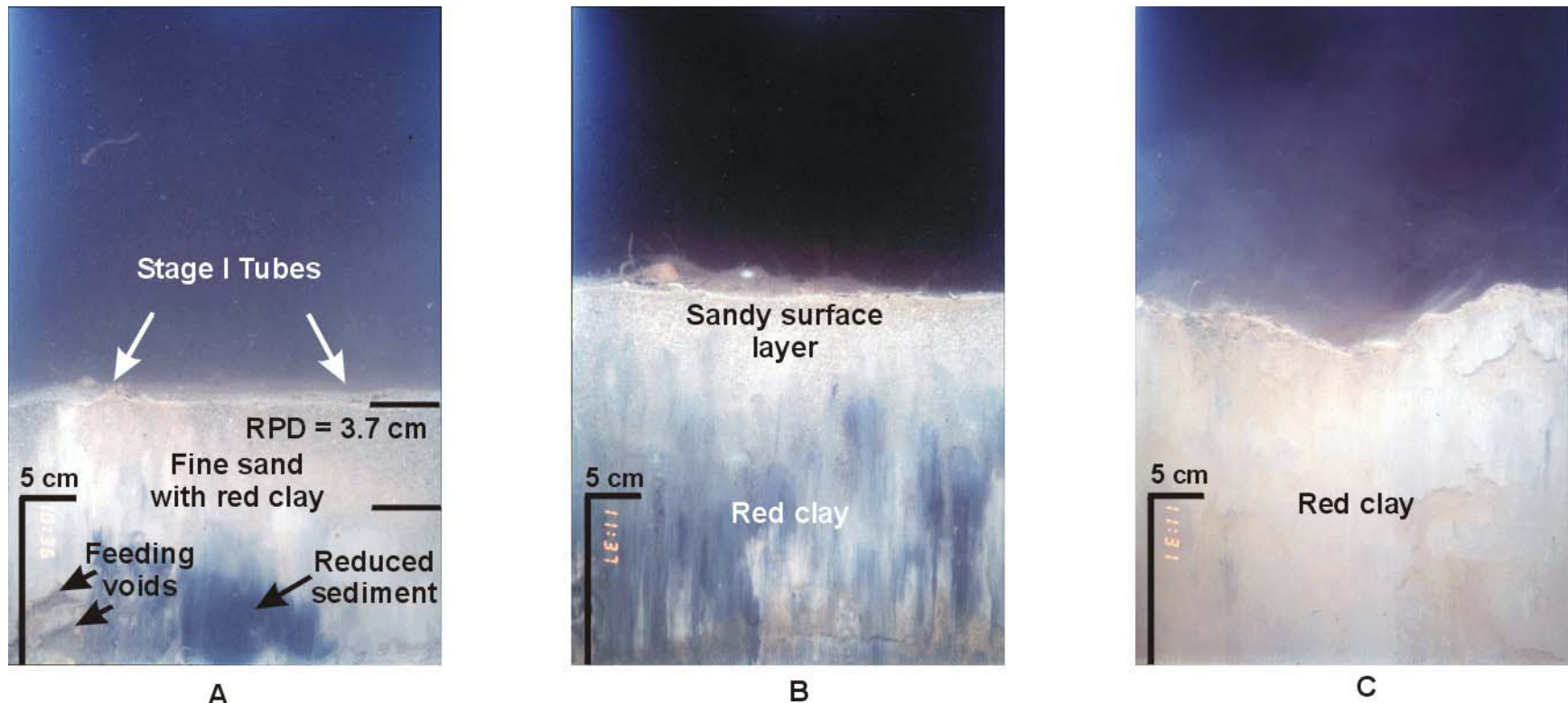


Figure 3.3-6. Three REMOTS images illustrating variability in the appearance (color and texture) of the red clay

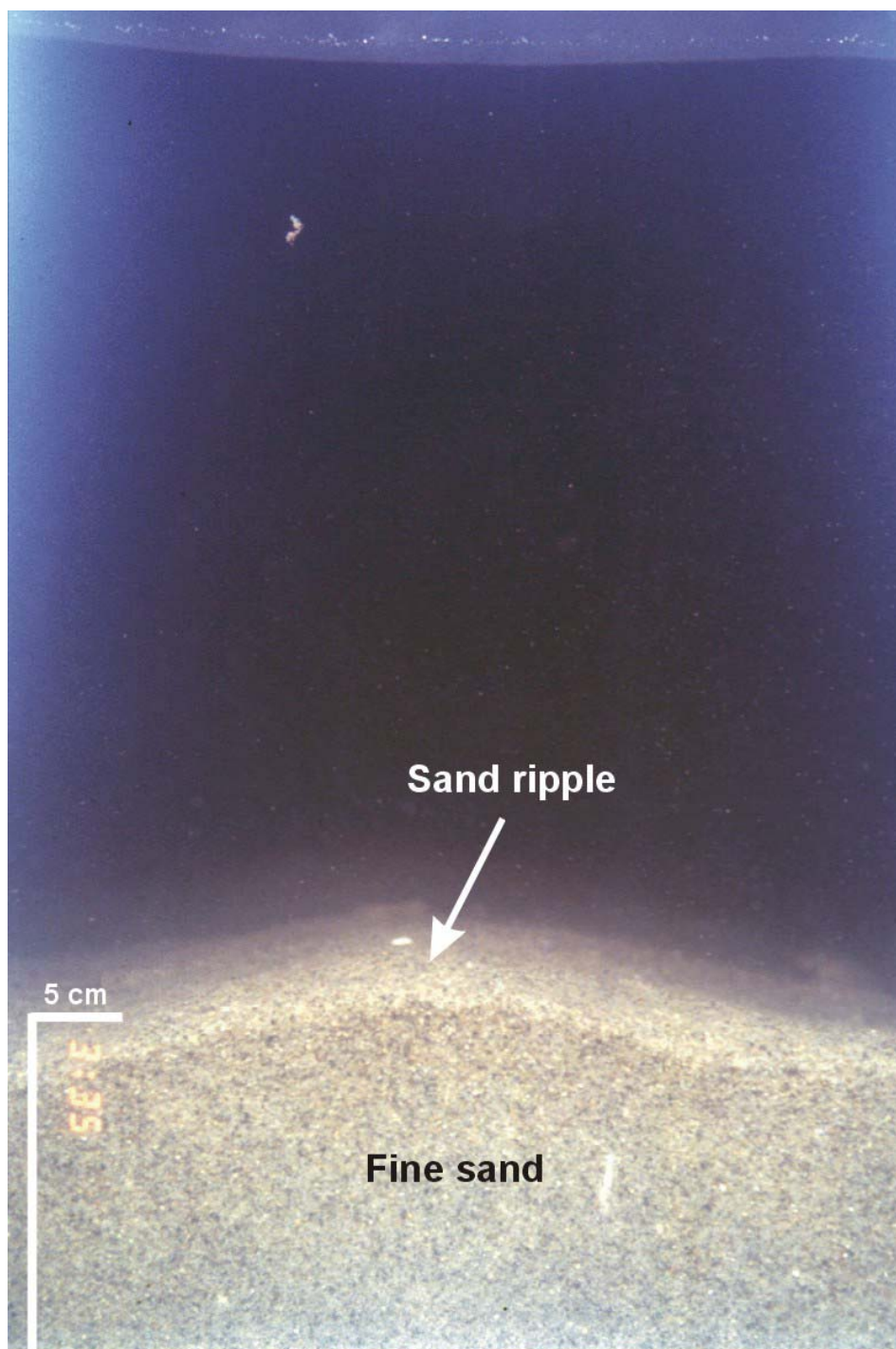


Figure 3.3-7. REMOTS image from Station SREF-11 illustrating the compact, rippled fine sand (major mode of 3 to 2 phi) that was the predominant sediment type present at all of the South Reference Area stations. This is an example of benthic habitat type SA.F (compact fine sand). The RPD depth extends below the camera's penetration depth (>5 cm).

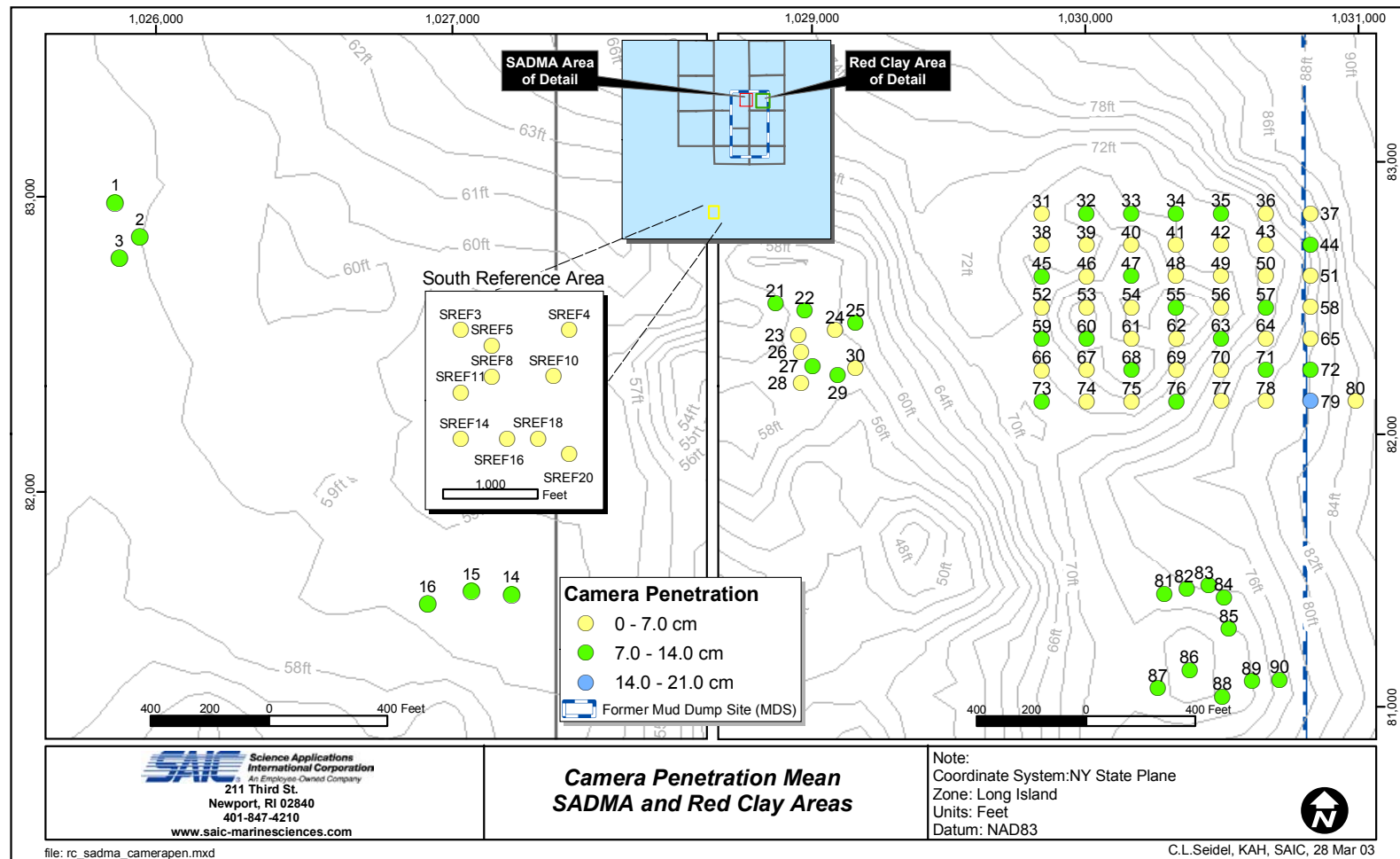


Figure 3.3-8. Map showing the average prism penetration depth at each of the Red Clay, SADMA, and South Reference Area stations.

at Station SREF3 where medium sand was observed. No other consistent spatial patterns or gradients in penetration depth were apparent within the sandy sediments of the South Reference Area. Small-scale boundary roughness values for the SADMA stations ranged from 0.9 cm at Station 2 to 1.9 cm at Station 14, with an overall average of 1.1 cm (Table 3.3-1 and Figure 3.3-9). Values in this range suggest a relatively smooth sediment surface, with only minor small-scale relief. The overall average of 1.1 cm for the Red Clay stations (Table 3.3-2) likewise is indicative of only minor small-scale surface relief. Although large, intact chunks of cohesive red clay were not detected in the REMOTS images, smaller red clay chunks along with rocks and/or pebbles were visible at the sediment surface in a number of images (Figure 3.3-10). A small percentage of the replicate images from the Red Clay Area exhibited biogenic surface roughness, due to the presence of dense worm (i.e., polychaete) tubes, hydroids, and amphipod stalks (i.e., “stick amphipods” of the Family Podoceridae), as well as biological surface reworking by burrowing infauna (burrow openings) at the sediment-water interface (Figure 3.3-11).

At the South Reference Area, the overall average boundary roughness value of 0.8 cm indicates little small-scale surface relief (Table 3.3-3). Surface roughness was attributed primarily to physical processes, with the exception of two replicate images, which displayed biogenic surface roughness due to sand dollars at the sediment-water interface. The relatively high boundary roughness of 1.7 cm at Station SREF3 was the result of sand rippling (sand waves) at the sediment surface; this was the only reference station displaying such sand ripples.

The plan view images supported the results of the REMOTS analysis for the SADMA stations, revealing the presence of mostly fine-grained sediments including silts, clays, and very fine sand. The sand detected in the plan view images likely represents ambient sediment that has washed over previously deposited, fine-grained dredged material. The sediment surface appeared rippled in most of the SADMA plan view images, supporting the idea that the sand is subject to periodic bedload transport (Figure 3.3-12).

The plan view images from the Red Clay stations also showed relatively good agreement with the REMOTS images, confirming the widespread occurrence of red clay (Figure 3.3-13). Thirteen of the Red Clay stations did not have an analyzable plan view image due to poor visibility in the overlying water column at the time the image was taken. Consistent with the REMOTS results, reference Station SREF-3 was the only reference station displaying sand rippling at the surface in the sediment plan view image. Furthermore, a significant amount of shell material was detected in the plan view images throughout the surveyed areas.

3.3.2 Biological Conditions

Three REMOTS parameters were used to assess benthic recolonization status and overall benthic habitat quality within the surveyed areas: apparent RPD depth, infaunal successional stage, and the Organism-Sediment Index (OSI).

Stage I, consisting of small, surface-dwelling organisms, was the dominant successional stage at the SADMA stations. This stage, either alone or in combination with Stage III, was noted in 92% of the replicate images and was the highest stage observed at three of the six SADMA

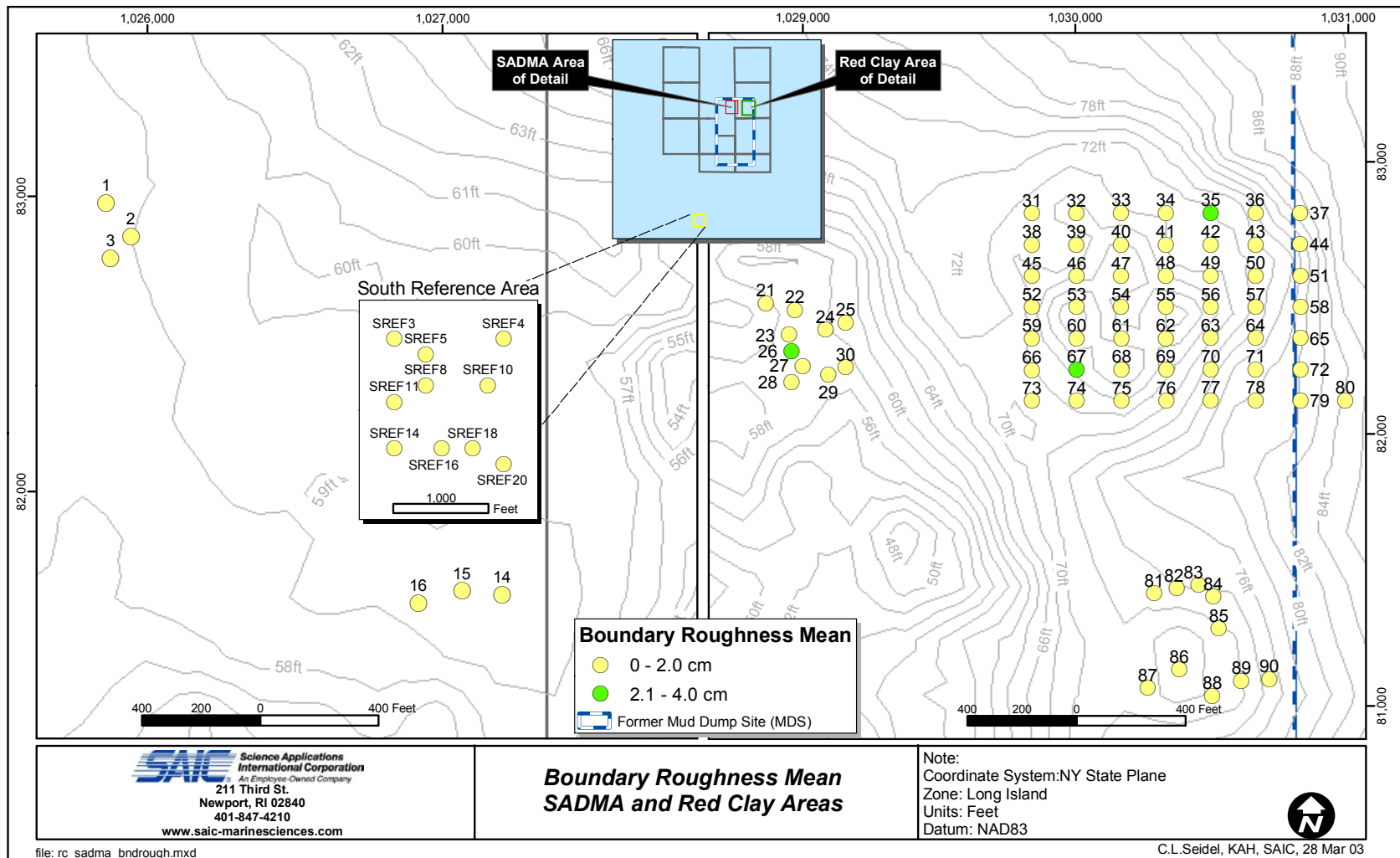


Figure 3.3-9. Map of average small-scale surface boundary roughness values at each of the Red Clay, SADMA, and South Reference Area stations.

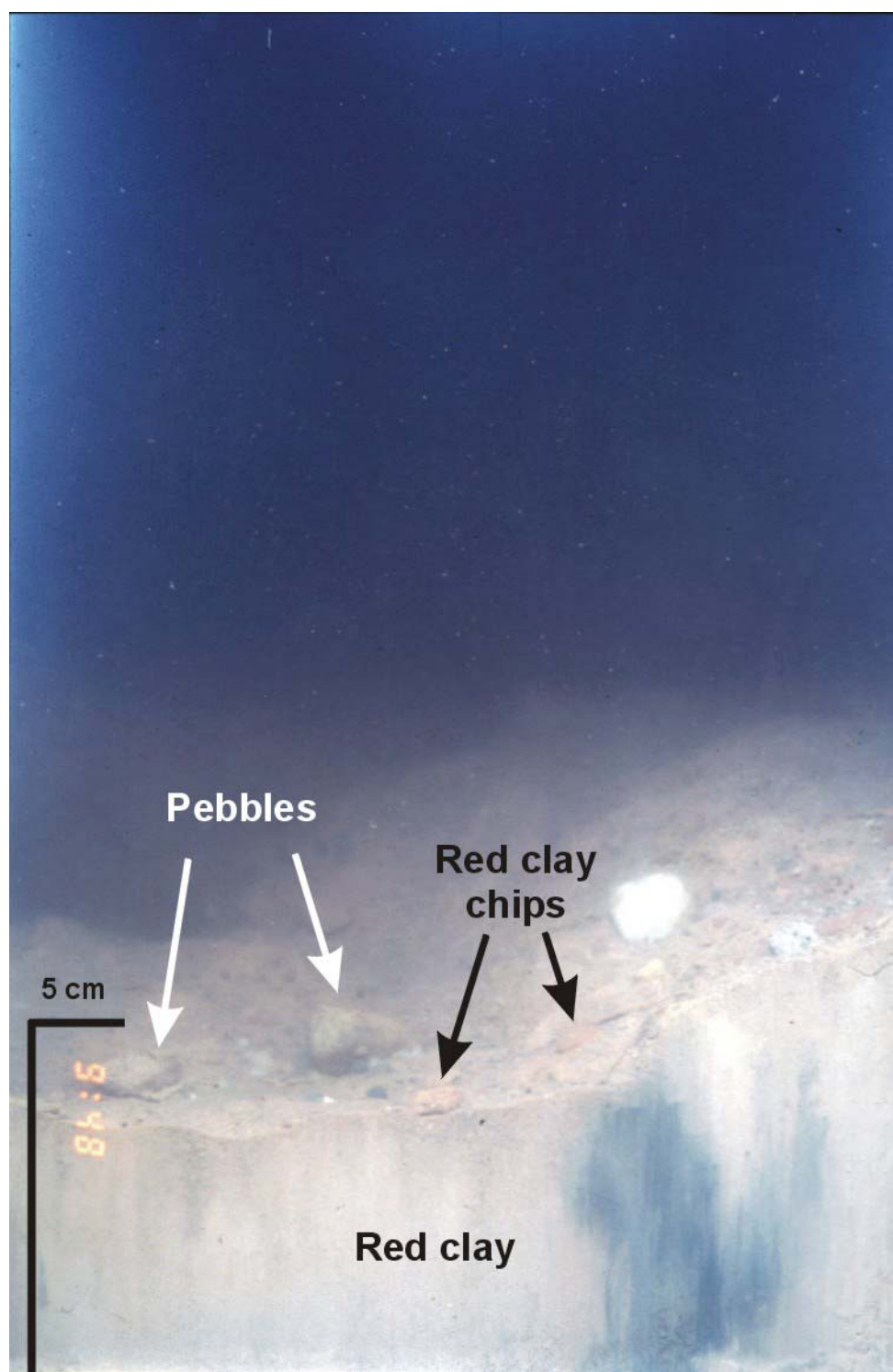
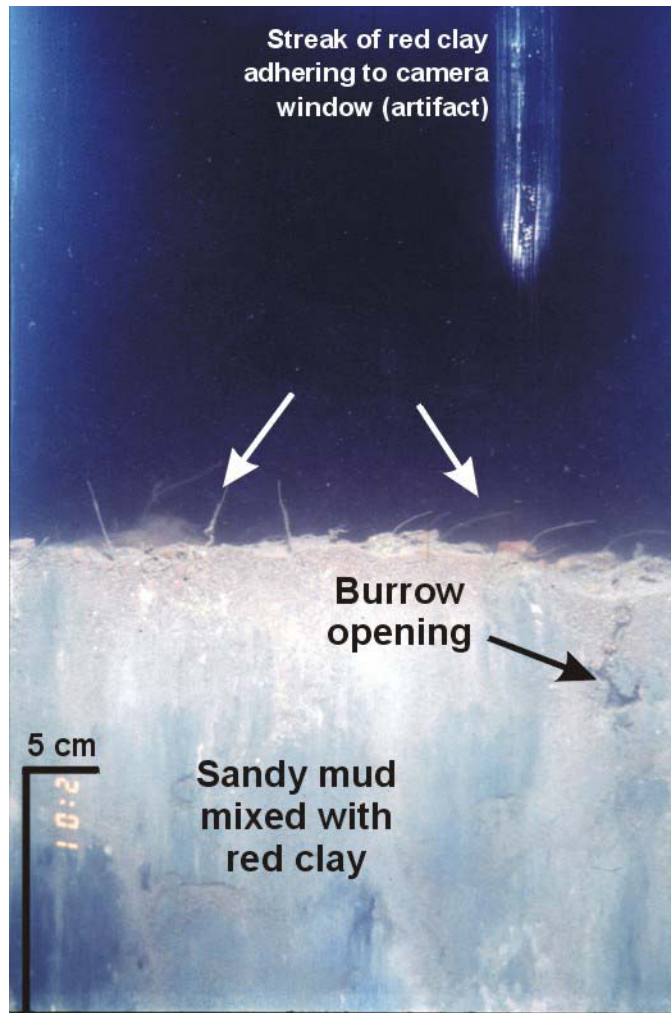
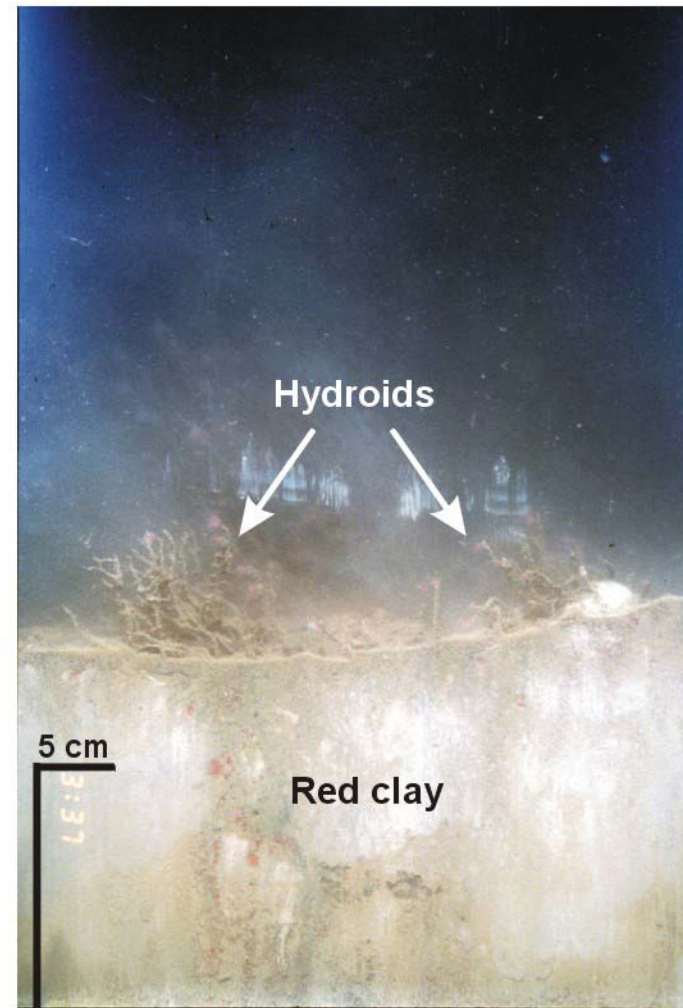


Figure 3.3-10. REMOTS image from Station 47 showing a minor amount of small-scale surface relief due to the presence of pebbles and cohesive red clay chips at the sediment surface.



A



B

Figure 3.3-11. REMOTS images from Stations 82 (left) and 61 (right) illustrating biogenic surface roughness due to the presence of stick amphipods (Family Podoceridae) and a burrow opening in image A and hydroids in image B.

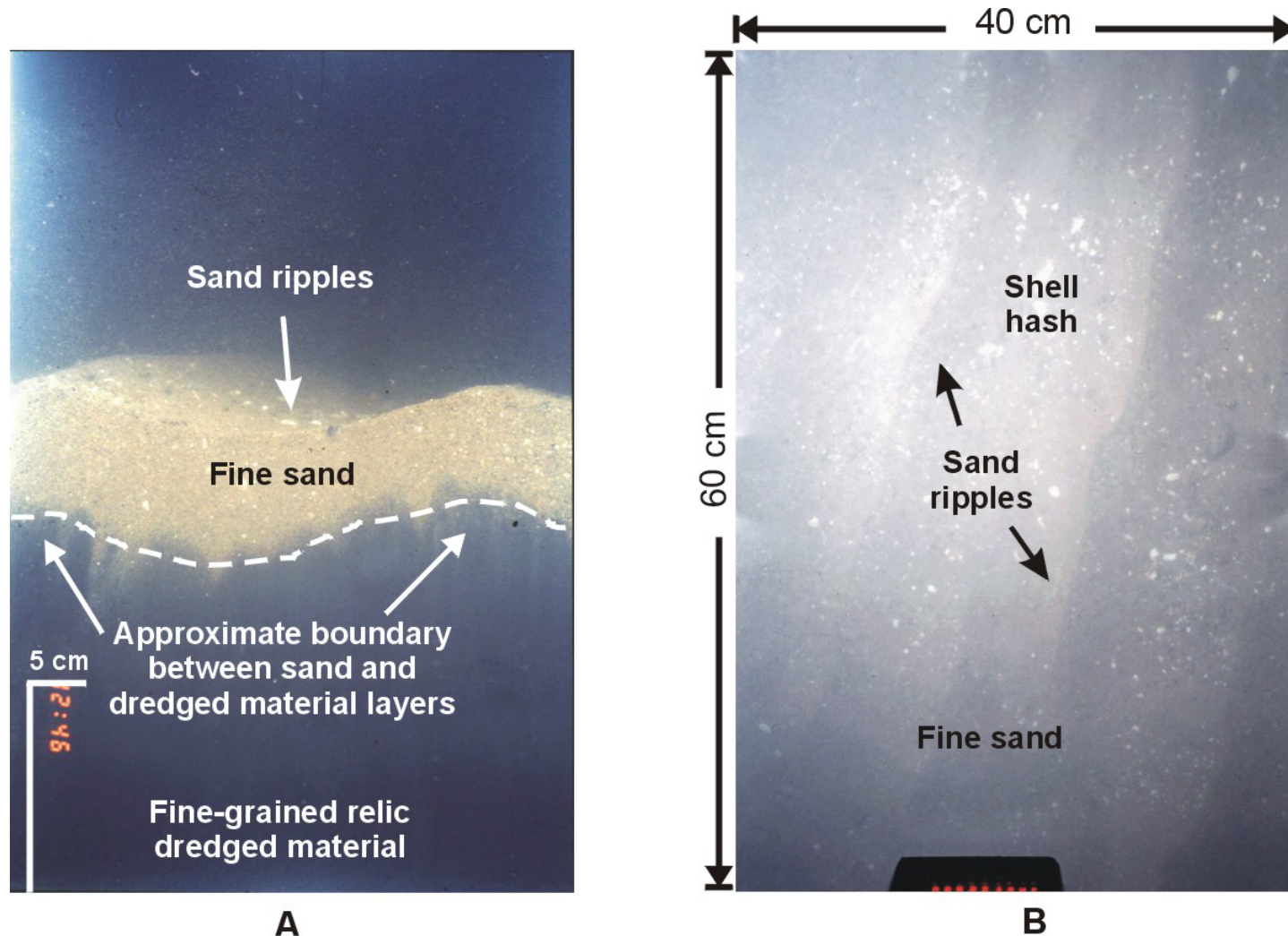


Figure 3.3-12. REMOTS image (left) and corresponding plan view photograph (right) from SADMA Station 16. The REMOTS image shows rippled fine sand over relic, black dredged material. The sand ripples and surface shell hash also are visible in the plan view photograph.

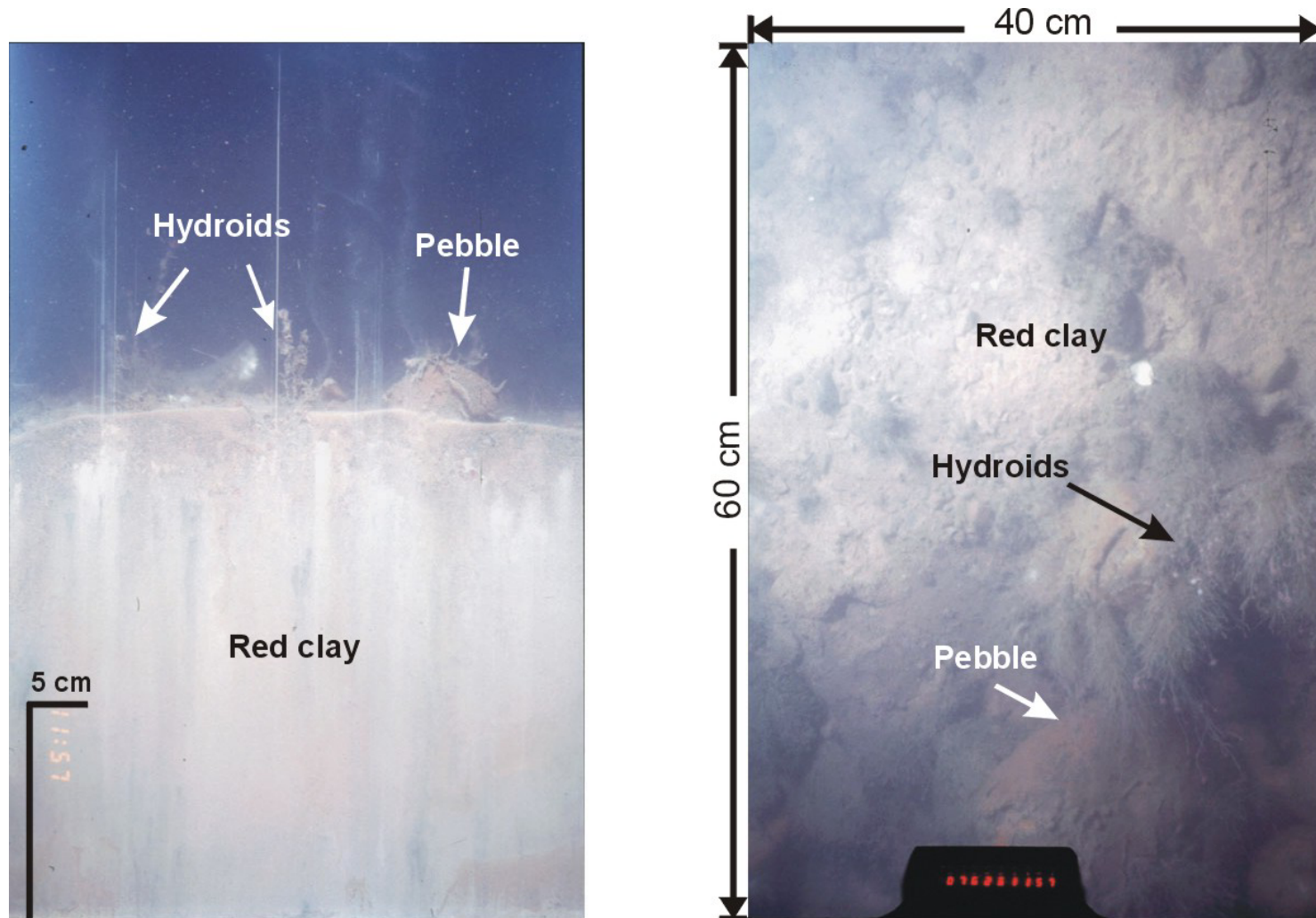


Figure 3.3-13. REMOTS image (left) and corresponding plan view photograph (right) from Station 83 showing the presence of pebbles with encrusting epifauna (primarily hydroids) at the surface of the red clay.

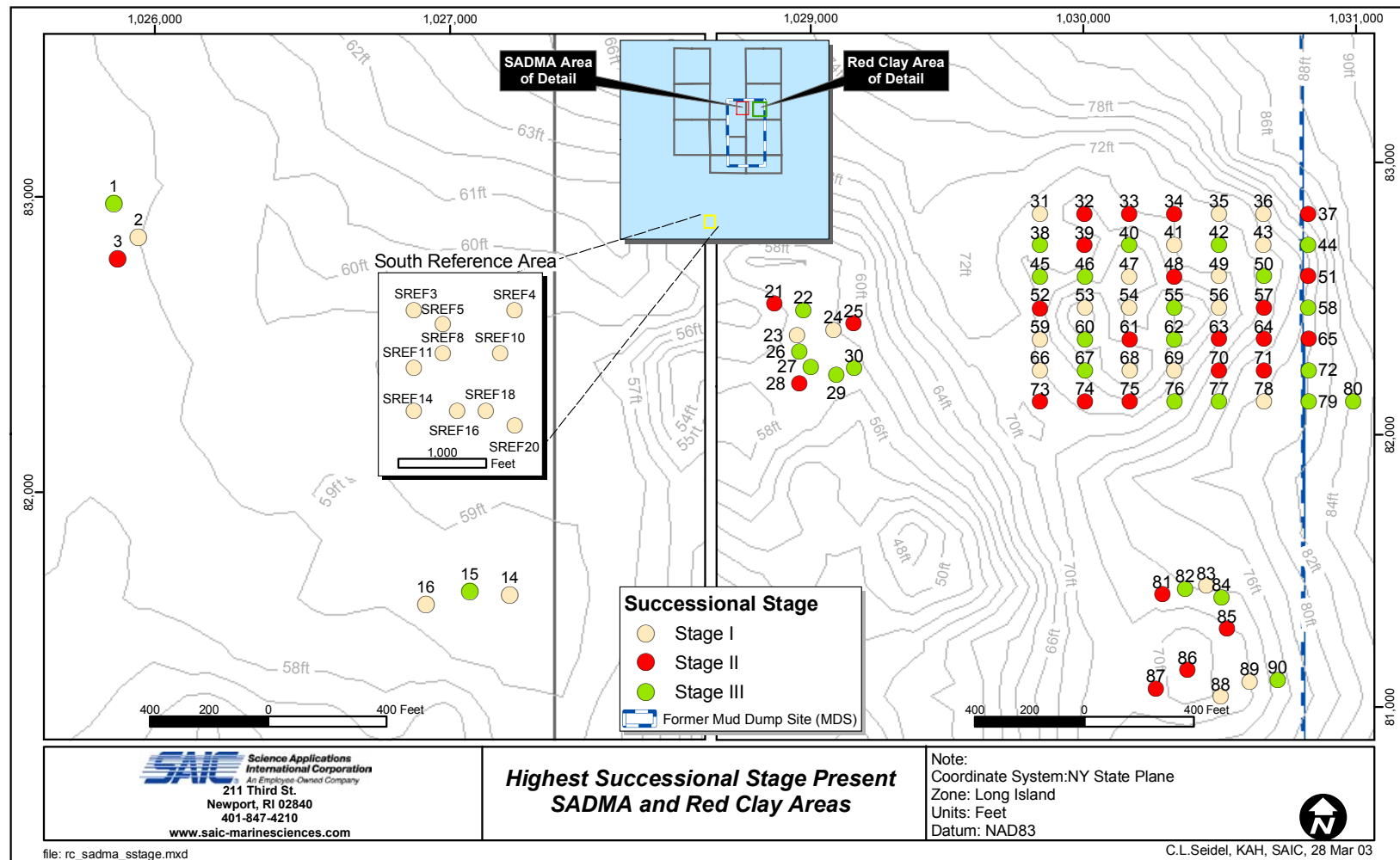


Figure 3.3-14. Map showing the highest successional stage observed for the two replicate REMOTS images collected at each of the SADMA, Red Clay, and South Reference Area stations

stations (Table 3.3-1 and Figure 3.3-14). Evidence of an advanced Stage III assemblage (i.e., active feeding voids visible in the subsurface sediments) was detected in 17% of the replicate images obtained at the SADMA stations. When present, Stage III organisms were accompanied by Stage I polychaetes at the sediment-water interface (Stage I on III successional status). Stage II stick amphipods (Family Podoceridae) were present in a single replicate image obtained at SADMA Station 3.

A variety of successional stages were observed at the Red Clay stations, including Stage I surface-dwelling organisms, Stage II infaunal amphipods, and Stage III larger-bodied infauna. Stage I by itself was observed in the majority of the replicate images (69 of 140, or 69%) collected at the Red Clay stations (Table 3.3-2 and Figure 3.3-14). However, there was a higher relative frequency of Stage III at the Red Clay stations than at the SADMA stations, with evidence of Stage III activity observed in 40 of the 140 replicate images (32%). Similar to the SADMA, the Stage III organisms were consistently accompanied by either Stage I polychaetes or Stage II stick amphipods at the sediment-water interface (Stage I on III and Stage II on III successional status, respectively; Figure 3.3-15). Four replicate images were given an indeterminate successional stage designation due to under-penetration of the camera prism in a hard bottom consisting of rocks and/or stiff clay.

Consistent with the REMOTS interpretation, a significant amount of biological activity was visible in the plan view images obtained at the Red Clay stations. Starfish, infaunal burrows, polychaete and amphipod tubes, hydroids, and crabs were some of the organisms and/or biological features that were readily observed at the surface of the red clay (e.g., Figures 3.3-13, 3.3-16, and 3.3-17). Not surprisingly, these organisms/features were also visible in the corresponding REMOTS images (e.g., Figures 3.3-13 and 3.3-18). Rocks and cohesive red clay clumps at the sediment surface appeared to be serving as a hard substrate for the attachment of hydroids (Figures 3.3-13 and 3.3-19).

Stage I by itself was observed at all of the South Reference Area stations (Table 3.3-3). The dominance of sand and the absence of organic-rich, fine-grained sediment at the South Reference Area precludes the establishment of a Stage III community consisting of subsurface deposit feeders. The plan view images showed sand dollars, often in dense aggregations, at some of the South Reference Area stations (Figure 3.3-20).

The RPD depth provides a measure of the apparent depth of oxygen penetration into the surface sediments and the degree of biogenic sediment mixing. The mean apparent RPD depths at stations within the SADMA ranged from 1.1 cm at Station 1 to 3.0 cm at Station 2, with an overall average of 1.8 cm indicating moderately well-oxygenated surface sediments (Table 3.3-1 and Figure 3.3-21). Apparent RPD depths were deeper at the Red Clay stations, with mean depths ranging from 0.9 cm at Station 89 to 5.0 cm at Station 21 (Table 3.3-2 and Figure 3.3-21). The overall average of 2.5 cm is indicative of well-oxygenated surface sediments. At a number of the Red Clay stations, the apparent RPD depth was considered “indeterminate” due to the lack of the normal color contrast between surface and subsurface sediments that is the basis for this measurement (Figure 3.3-22). No evidence of redox rebound intervals, low sediment dissolved oxygen conditions, or sediment methane was detected in any of the REMOTS images obtained in the June 2002 survey.

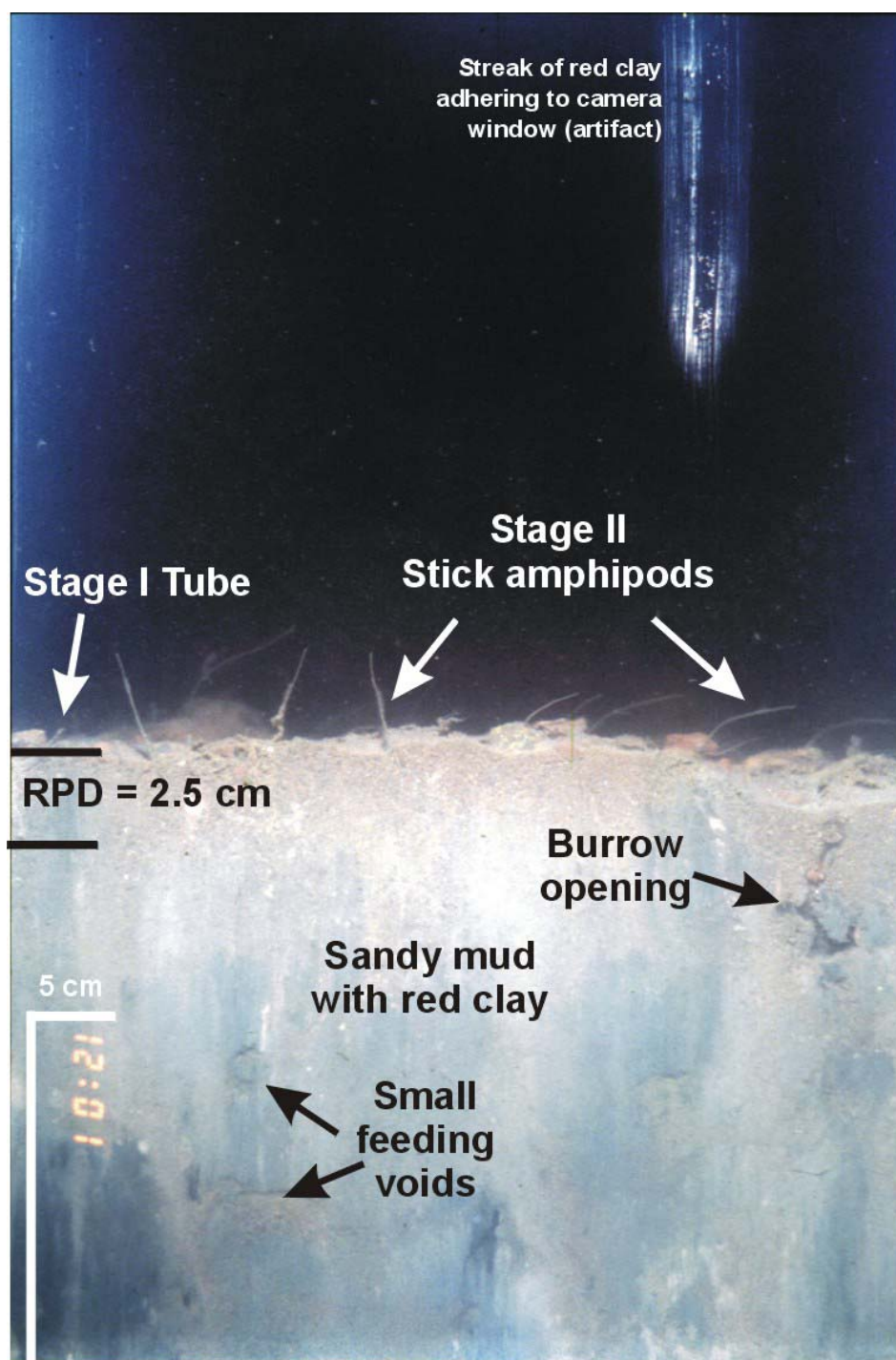


Figure 3.3-15. REMOTS image from Red Clay Station 82 illustrating Stage II on III. Numerous Stage II stick amphipods (Family Podoceridae) are visible at the sediment surface, while several small Stage III feeding voids occur at depth within the red clay. The presence of these advanced successional stages and a well-developed RPD depth of 2.5 cm resulted in an OSI value of +9 (undisturbed benthic habitat quality) for this image.

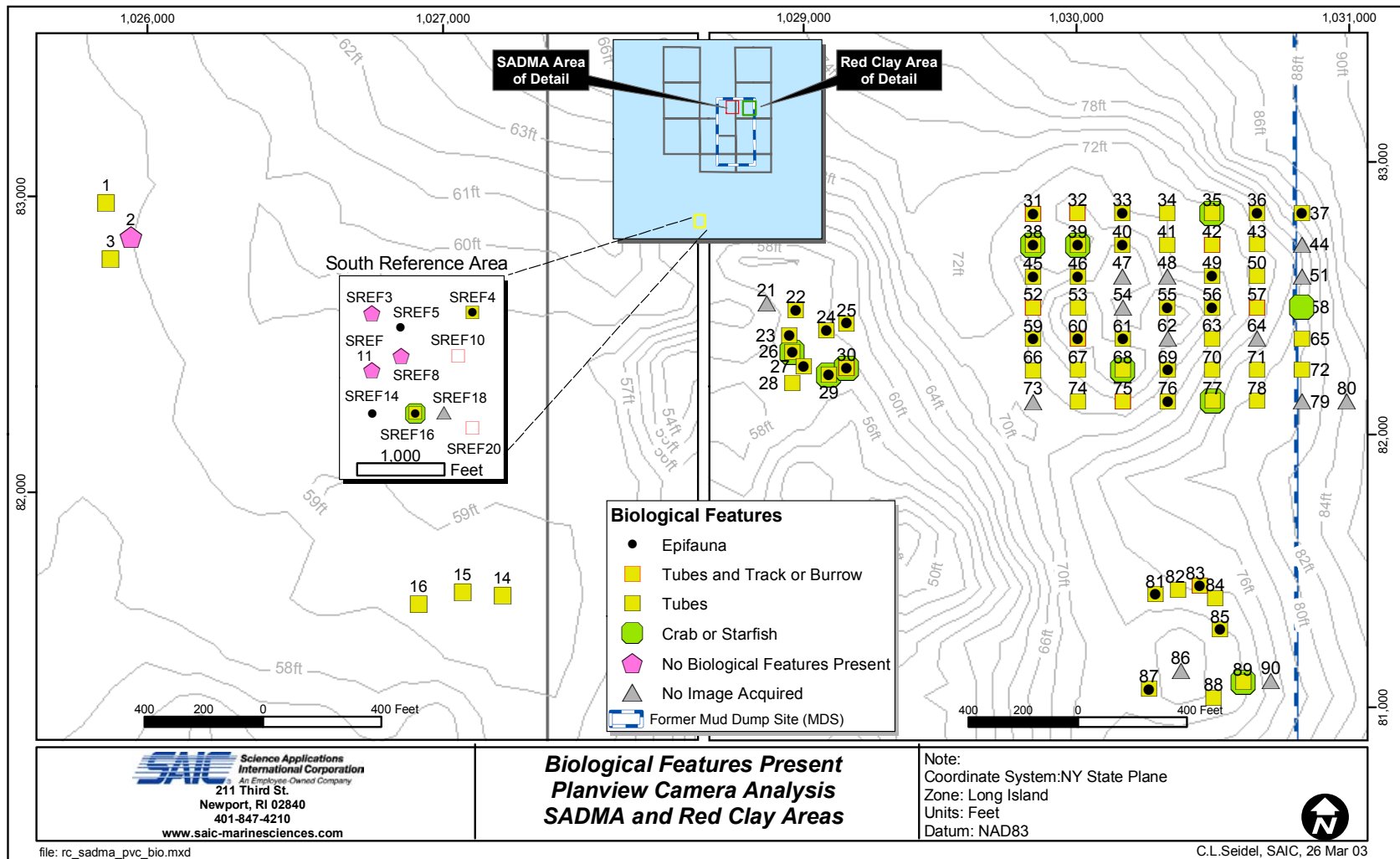


Figure 3.3-16. Map showing the various biological features observed in the plan view images at the SADMA, Red Clay, and South Reference Area stations

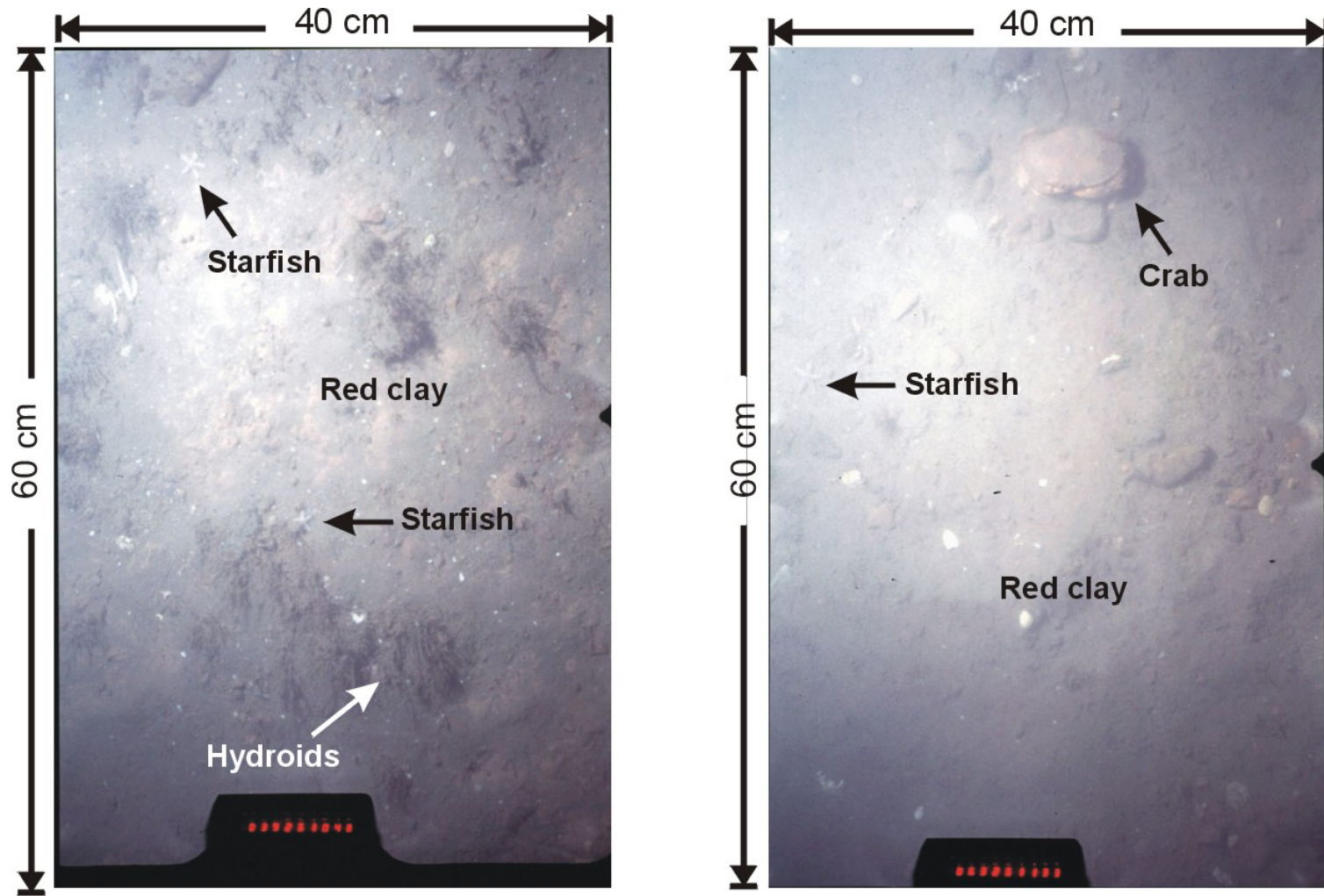


Figure 3.3-17. Sediment plan view photographs from Station 30 (left) and 89 (right) showing a variety of epifauna at the surface of the red clay

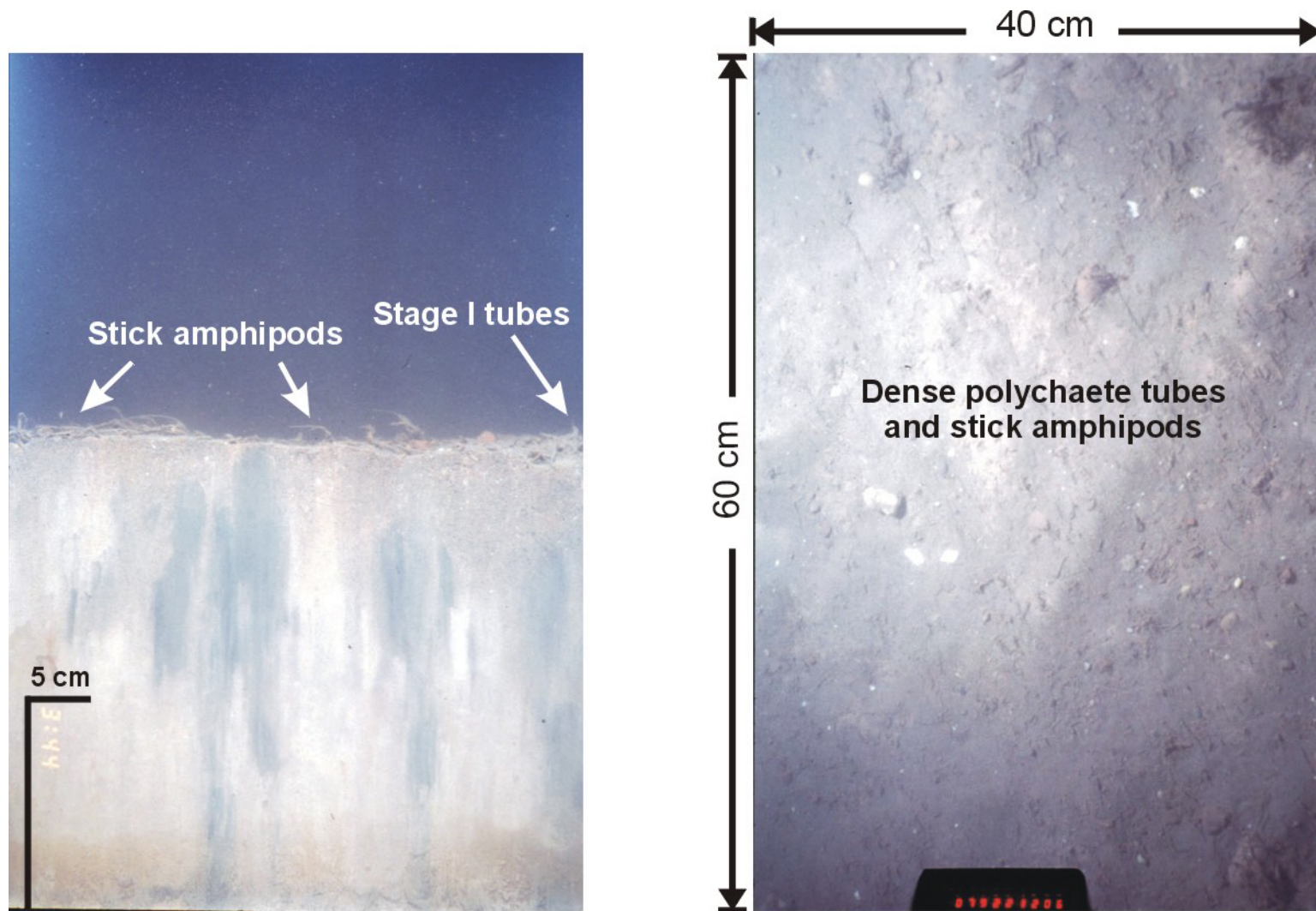


Figure 3.3-18. REMOTS image (left) and corresponding plan view photograph (right) showing stick amphipods (Family Podoceridae) and polychaete tubes at the surface of the red clay at Station 33

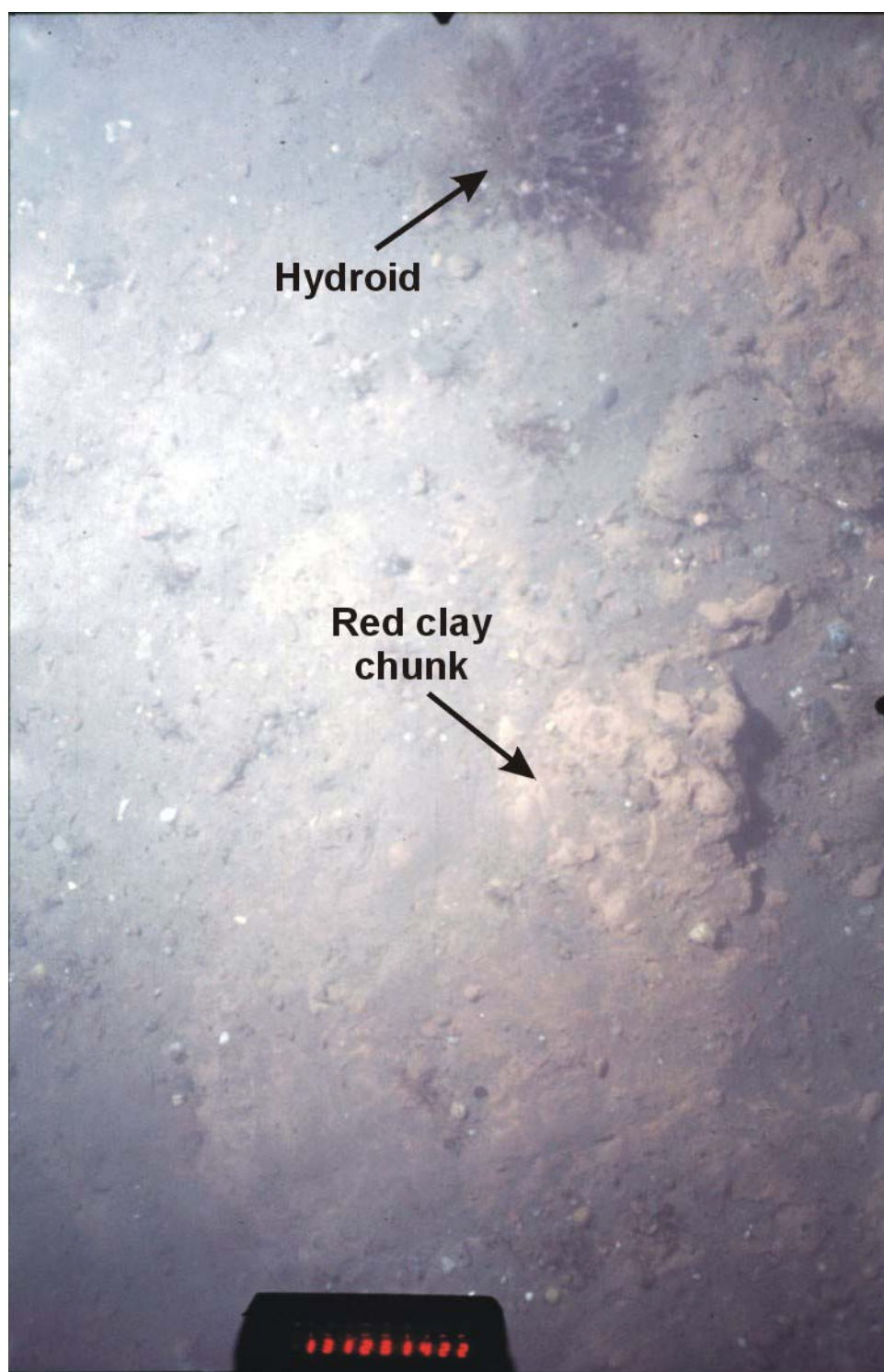


Figure 3.3-19. Plan view image from Station 46 showing cohesive chunks of red clay visible through a thin veneer of silt. The hydroid in the upper part of the image appears to be attached to the surface of a cohesive clay chunk.

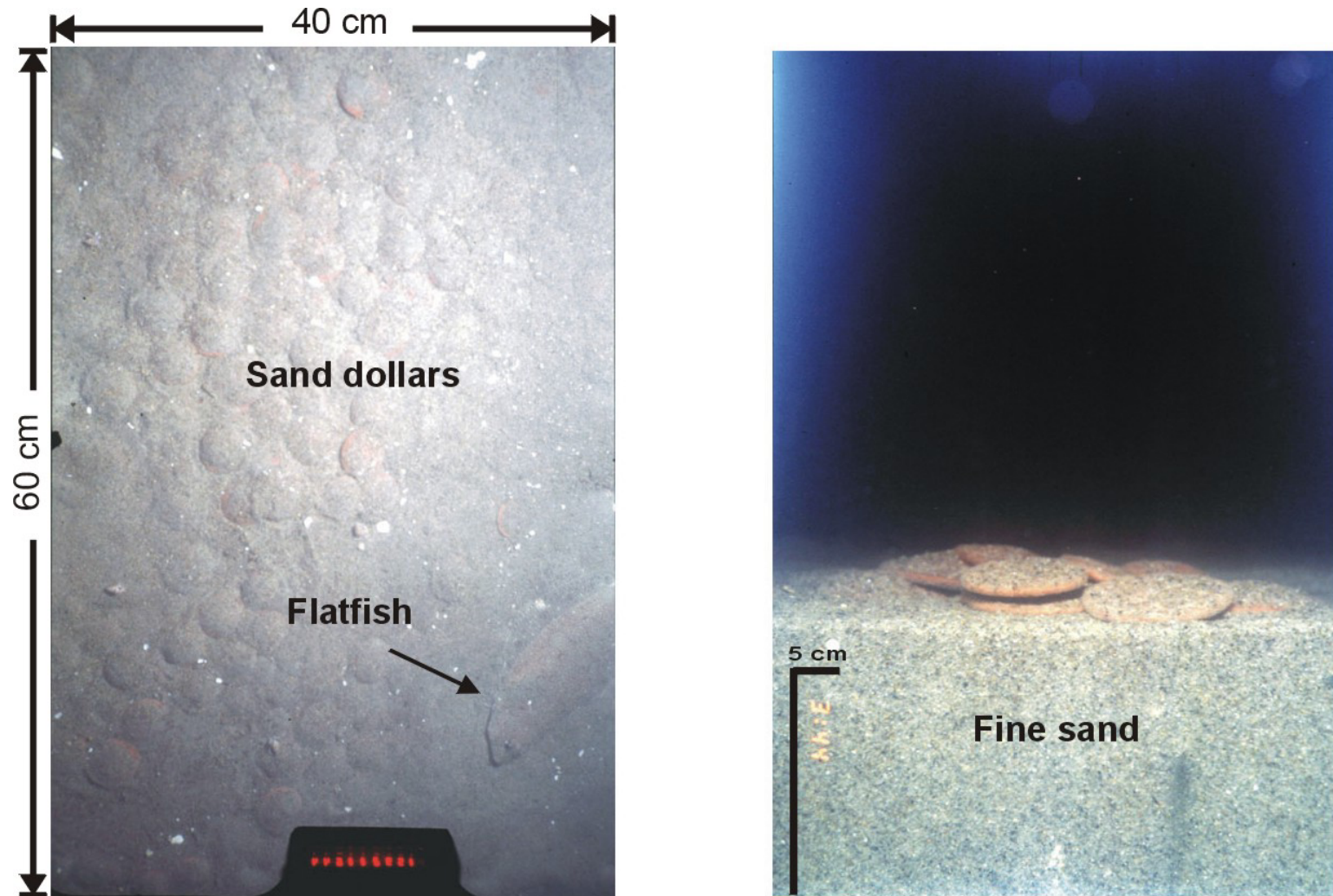


Figure 3.3-20. Plan view image (left) and corresponding REMOTS image (right) from South Reference Area Station SREF-5 showing a dense aggregation of sand dollars at the sediment surface. A flatfish also is visible at the sediment surface in the plan view image (left).

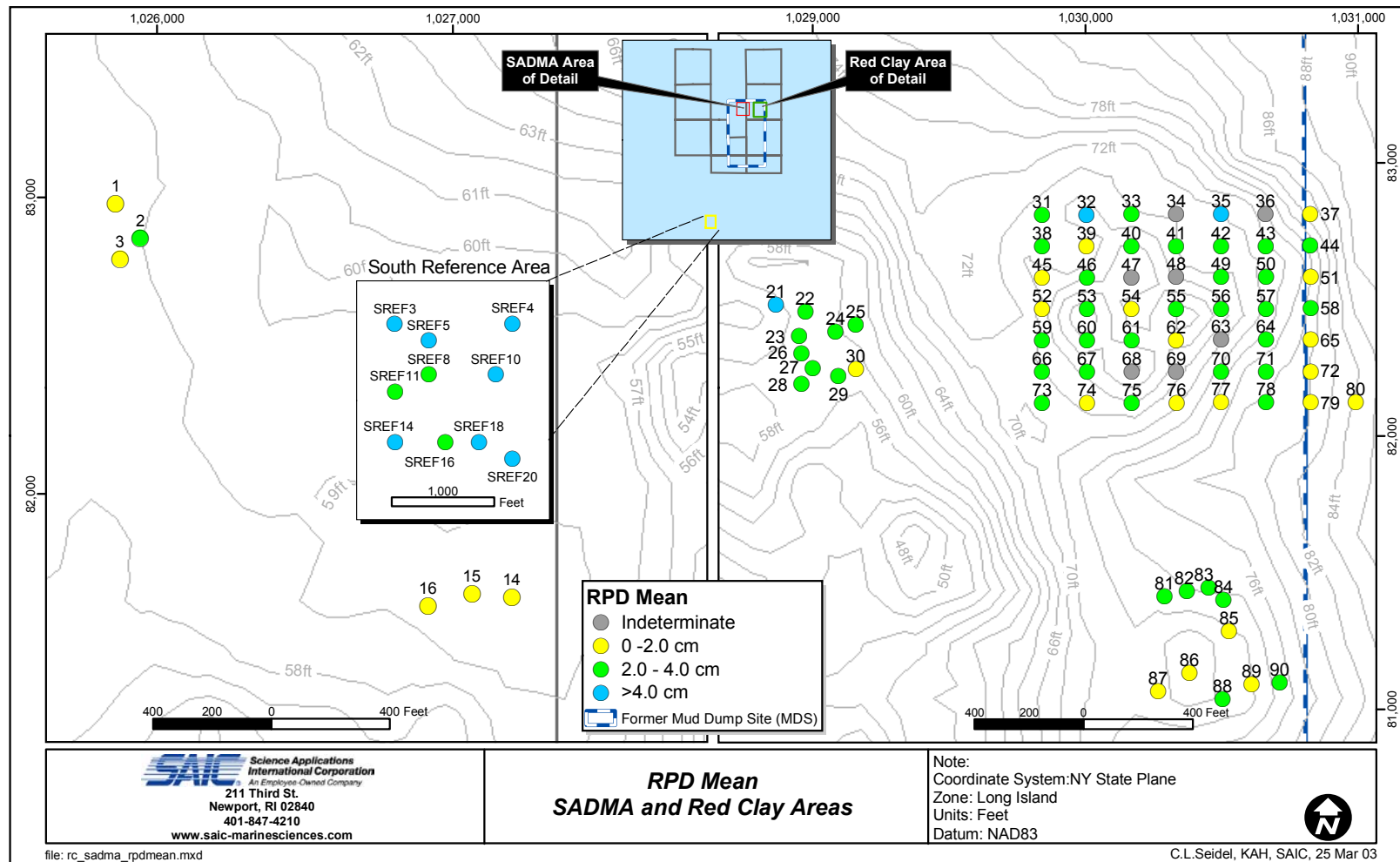


Figure 3.3-21. Map of mean apparent RPD depths at the SADMA, Red Clay, and South Reference Area stations

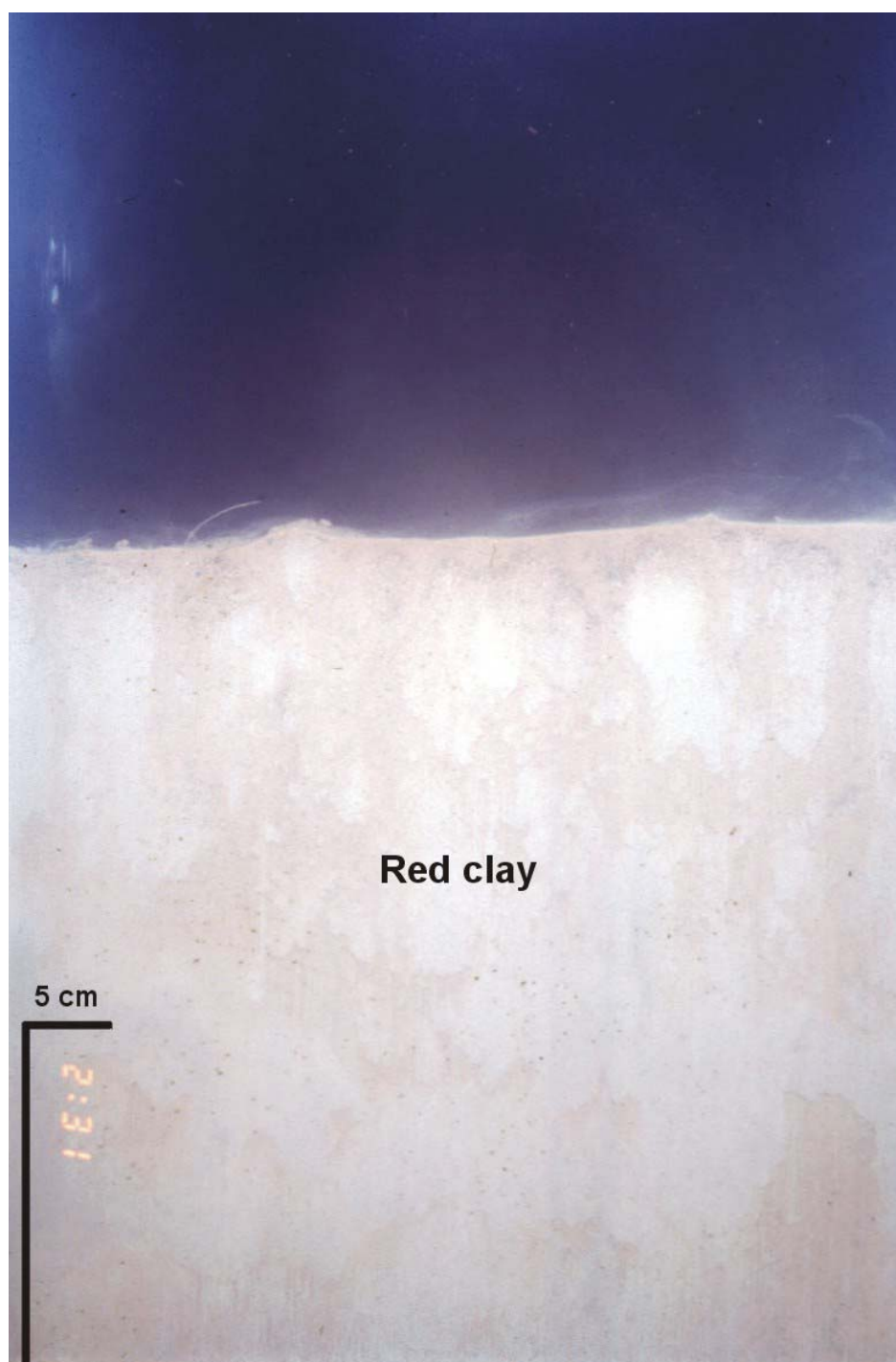


Figure 3.3-22. REMOTS image from Red Clay Station 63 showing homogenous red clay extending from the sediment surface to below the imaging depth of the sediment-profile camera (i.e., red clay depth > penetration depth). The red clay is very homogenous in both color and texture; the absence of a contrast between lighter-colored, aerobic surface sediments and underlying darker, reduced subsurface sediments makes it impossible to measure the RPD depth.

The mean apparent RPD depths at the South Reference Area stations were higher than those observed over the SADMA and Red Clay Area, ranging from 2.9 cm at Station SREF-16 to >6.3 cm at Station SREF-5 (Table 3.3-3). The RPD depths extended beyond the penetration depth of the camera prism at the majority of these sandy stations (i.e., RPD > pen) and are therefore conservative measurements. None of the stations occupied at the South Reference Area showed any evidence of low sediment dissolved oxygen conditions, visible redox rebounds, or methane gas bubbles.

Mean OSI values for stations within the SADMA area ranged from +4.0 at Stations 14 and 16 to +5.5 at Station 15 (Table 3.3-1 and Figure 3.3-23). The overall average value of +4.7 is indicative of moderately disturbed benthic habitat quality, reflecting the dominance of Stage I organisms and associated RPD depths that were somewhat shallow (Figure 3.3-24). Average OSI values for stations over the red clay deposit were higher, ranging from +3.0 at Station 89 to +9.5 at Station 29 (Table 3.3-2 and Figure 3.3-23). The overall value of +6.5 is indicative of undisturbed benthic habitat quality and reflects deeper mean RPD depths and a higher frequency of advanced Stage III activity. Of the 70 Red Clay stations, 31 (44%) displayed mean OSI values >+6.0 (highly colonized or undisturbed). Values on the lower end of the scale ($\leq +6$) generally occurred at stations with shallow RPD depths and only a low order successional stage (Stage I). Calculation of the OSI was not possible at a number of stations because either the RPD depth and/or the successional stage was indeterminate.

At the South Reference Area stations, benthic habitat quality as reflected in the OSI was identical to that at the Red Clay stations and higher than observed at the SADMA stations. Mean OSI values ranged from +5.5 at Stations SREF-16 and SREF-8 to +7.0 at Stations SREF-3, SREF-5, SREF-10, SREF-14, and SREF-18, with an overall average of +6.5 again indicating undisturbed or non-degraded benthic habitat quality (Table 3.3-3). The relatively high OSI values at the South Reference Area stations reflect relatively deep (> 3 cm) RPD depths and the widespread presence of Stage I organisms.

3.4 Benthic Grab Sampling

3.4.1 SADMA Stations

On average, the surface sediment collected at the SADMA stations had approximately equal proportions of fine sand (47.6%) and silt-clay (47.4%), with relatively insignificant amounts of medium/coarse sand and gravel (Table 3.4-1). The relative proportions of fine sand and silt-clay varied from 31% to 67% at the individual stations (Table 3.4-1).

A complete set of data showing all of the benthic taxa collected at the Red Clay, SADMA, and South Reference Area stations is provided in Appendix C. Organism density (number of individuals per m²) varied somewhat among the five SADMA stations, from 13,650 individuals/m² at Station 3 to 32,575 individuals/m² at Station 15 (Table 3.4-2). The number of taxa collected in each grab sample also varied among the five stations, ranging from 17 to 50 (Table 3.4-2). Due to its comparatively low organism density and number of taxa, Station 3 had the lowest species diversity, evenness and richness among the five stations, while Station 5 has the highest diversity, evenness and richness values (Table 3.4-2).

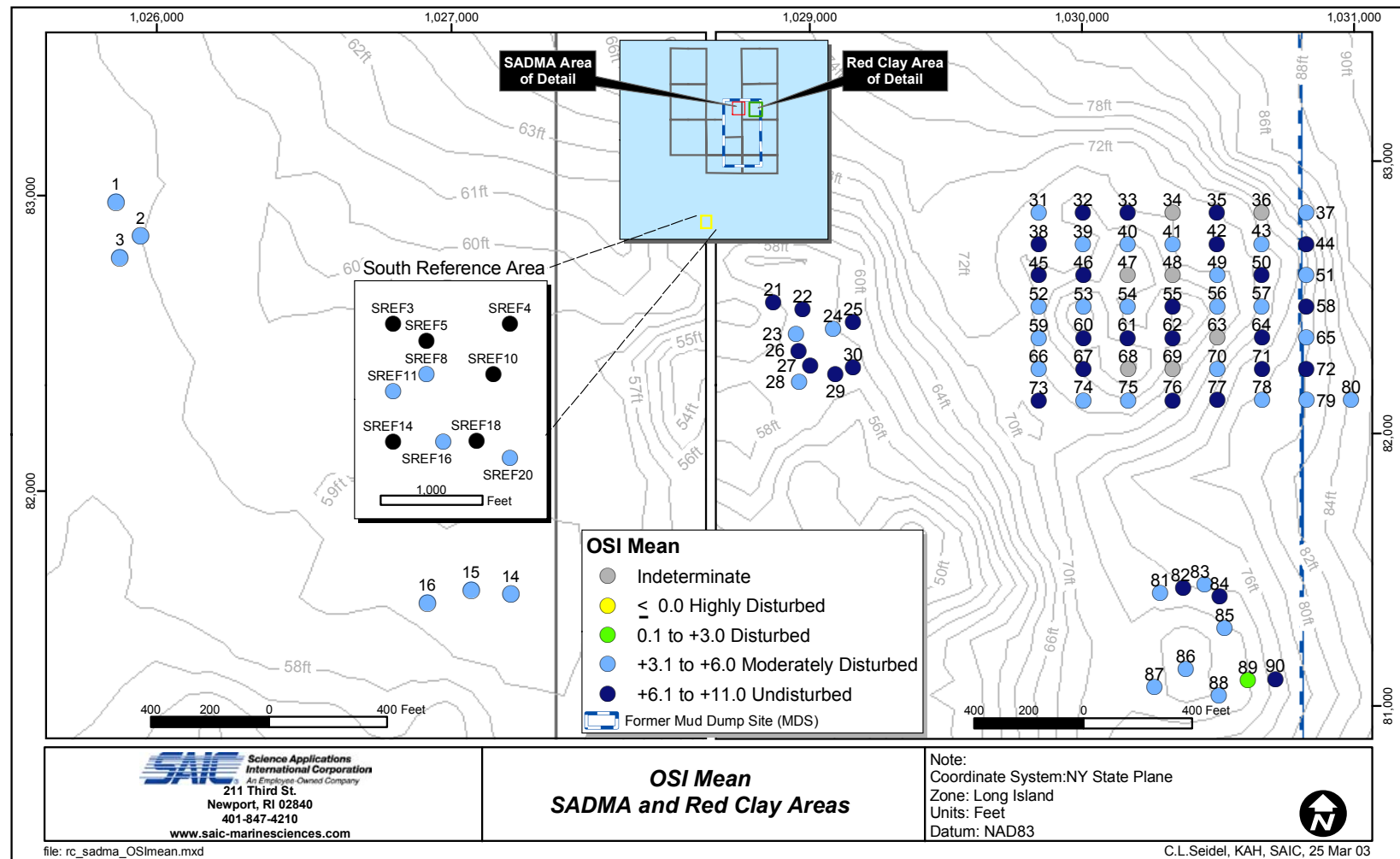


Figure 3.3-23. Map of mean OSI values at the SADMA, Red Clay, and South Reference Area stations

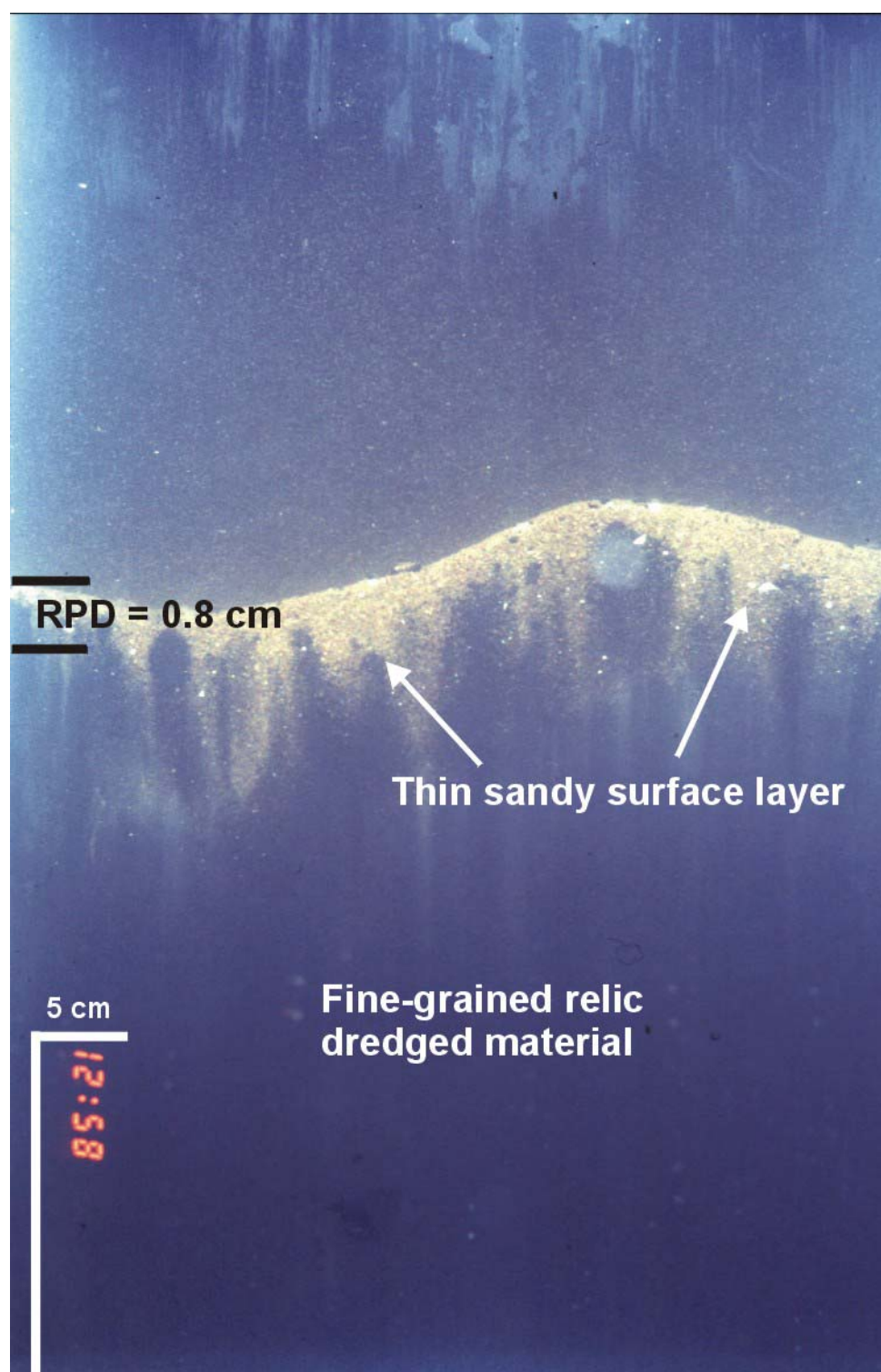


Figure 3.3-24. REMOTS image from SADMA Station 14 showing a relatively shallow RPD depth of 0.8 cm and an absence of Stage III organisms, resulting in an OSI value of +3 (moderately disturbed benthic habitat quality).

Table 3.4-1.
Summary of Grain Size Analysis Results for the Benthic Grab Samples

	% Coarse Sand and Gravel	% Medium Sand	% Fine Sand	% Silt-clay
<u>Red Clay Stations</u>				
24	1.9	10.5	60.0	28.1
26	3.9	15.2	52.3	28.7
34	5.1	5.5	64.1	25.3
39	4.2	18.9	42.6	34.3
43	8.6	16.0	24.3	51.1
44	11.4	7.1	20.5	61.0
50	5.8	11.4	18.2	64.6
51	1.7	6.5	51.1	40.7
55	1.1	1.8	5.6	91.5
57	2.6	10.3	54.6	32.4
64	10.8	11.2	40.2	37.8
66	6.5	4.2	64.5	24.8
74	2.7	6.9	52.7	37.6
78	15.1	15.4	36.7	32.9
85	25.0	12.2	41.3	21.6
Average	7.1	10.2	41.9	40.8
<u>SADMA Stations</u>				
2	3.3	8.0	40.2	48.5
3	0.1	1.3	31.6	67.0
14	0.9	2.7	62.2	34.2
15	2.5	3.8	62.4	31.3
16	0.3	2.3	41.4	56.0
Average	1.4	3.6	47.6	47.4
<u>South-Ref Stations</u>				
S-4	0.8	50.2	46.4	2.7
S-8	0.2	19.7	75.7	4.4
S-14	0.0	9.5	88.8	1.7
Average	0.3	26.5	70.3	2.9

Table 3.4-2.
Summary of Benthic Community Parameters for the Five SADMA Stations

	Station				
	2	3	14	15	16
No. individuals/m ²	15,425	13,650	14,375	32,575	22,150
No. of taxa	34	17	41	50	40
Shannon-Weiner diversity (log _e)	1.73	0.78	1.97	2.33	1.18
Margelef's species richness	3.42	1.68	4.18	4.72	3.90
Pielou's evenness	0.49	0.27	0.53	0.59	0.32
Fifteen most abundant taxa for all 5 stations combined (percent of total abundance in parentheses)	Nucula proxima (57%) Cirratulidae (LPIL) (7%) Tharyx acutus (5%) Tellina agilis (5%) Mediomastus (LPIL) (4%) Pitar morrhuanus (4%) Polygordius (LPIL) (4%) Levinsenia gracilis (3%) Tubificidae (LPIL) (1%) Mediomastus ambiseta (1%) Pellucistoma (LPIL) (1%) Aricidea (LPIL) (1%) Spiophanes bombyx (1%) Aricidea catherinae (1%) Apopronospio pygmaea (<1%)				

The most abundant organism at the SADMA stations was overwhelmingly the bivalve mollusc *Nucula proxima* (nut clam), which accounted for 57% of the total number of individuals collected at the five stations. There also were a number of annelids among the numerical dominants, including the Stage I polychaetes *Ceratonereis* (LPIL), *Tharyx acutus*, *Mediomastus* sp., *Mediomastus ambiseta*, *Polygordius* sp., *Spiophanes bombyx*, and *Apoiprionospio pygmaea*; the Stage III polychaetes *Aricidea catherinae* and *Levinsenia gracilis*; and Stage I oligochaetes of the Family Tubificidae (Table 3.4-2). In addition, the bivalve molluscs *Tellina agilis* (dwarf Tellin) and *Pitar morrhuanus* (false quahog) were among the top 15 most abundant taxa at the SADMA stations (Table 3.4-2).

3.4.2 Red Clay Stations

On average, the grain size distribution at the Red Clay stations consisted of roughly equal proportions of fine sand (42%) and silt-clay (41%), with minor amounts of medium sand (10%) and coarse sand/gravel (7%; Table 3.4-1). The silt-clay and fine sand fractions generally were inversely proportional at most stations. Silt-clay ranged from 91.5% at Station 55 to 21.6% at Station 85, while fine sand ranged from 5.6% at Station 55 to 64.5% at Station 66 (Table 3.4-1). Stations 78, 43, and 39 had higher proportions of medium sand, and coarse sand/gravel was relatively abundant at Stations 78 and 85. In general, there was a wider diversity of different sediment size fractions at the Red Clay stations compared to the SADMA and South Reference Area stations.

Organism density (number of individuals per m²) varied widely among the fifteen Red Clay stations, ranging from 550 individuals/m² at Station 55 to 37,675 individuals/m² at Station 78 (Table 3.4-3). Similar to the SADMA stations, the nut clam *Nucula proxima* was the dominant taxa at the Red Clay stations, accounting for 28% of all the individuals collected in the fifteen grab samples (Table 3.4-3). *Nucula proxima* is a common Stage II species that is relatively insensitive to sediment contamination and has been reported as one of the basic, dominant infauna of the New York Bight (Chang et al. 1992).

Other bivalves found among the fifteen most abundant taxa at the Red Clay stations were the false quahog, *Pitar morrhuanus*, and the little cockle, *Cerastoderma pinnulatum* (Table 3.4-3). A number of annelids were also relatively abundant, including both suspension-feeding (i.e., Stage I) and subsurface deposit-feeding (i.e., Stage III) polychaetes. Among the Stage I polychaetes were *Cirratulidae*, *Cossura soyeri*, *Pherusa affinis*, *Polygordius* sp. and *Medimastus* sp., while Stage III taxa included *Levinsenia gracilis*, *Scoletoma* sp. AA, *Scoletoma verrilli*, *Nephtys incisa*, and *Ninoe nigripes* (Table 3.4-3).

The highest number of taxa (58) was collected at Station 24, while comparatively few taxa (13) were found at Station 55 (Table 3.4-3). Reflecting a disproportionately high number of *Nucula proxima* (19,400 individuals/m²), Station 78 had the lowest Shannon-Weiner diversity (1.91) and Pielou's evenness (0.50). At the other fourteen stations, diversity ranged from 2.23 at Station 34 to 3.26 at Station 24, while evenness ranged from 0.59 at Station 34 to 0.84 at Station 26 (Table 3.4-3). Station 24 has the highest species richness (6.13), and Station 55 had the lowest value of 1.90 (Table 3.4-3).

Table 3.4-3.
Summary of Benthic Community Parameters for the Fifteen Red Clay Stations

	Stations														
	24	26	34	39	43	44	50	51	55	57	64	66	74	78	85
No. individuals/m ²	11000	8350	15075	13375	1875	6950	3875	18325	550	6500	12375	3925	10950	37675	8075
No. of taxa	58	40	44	43	19	28	27	39	13	34	37	34	33	46	37
Shannon-Weiner diversity (log-e)	3.26	3.08	2.23	2.58	2.33	2.57	2.58	2.45	2.35	2.67	2.51	2.70	2.49	1.91	2.59
Margalef's species richness	6.13	4.32	4.47	4.42	2.39	3.05	3.15	3.87	1.90	3.76	3.82	3.99	3.44	4.27	4.00
Pielou's evenness	0.80	0.84	0.59	0.69	0.79	0.77	0.78	0.67	0.92	0.76	0.70	0.77	0.71	0.50	0.72
Fifteen most abundant taxa for all 15 stations combined (percent of total abundance in parentheses)	Nucula proxima (28%) Levinsenia gracilis (14%) Cirratulidae (LPIL) (11%) Scoletoma sp. AA (6%) Scoletoma verrilli (5%) Pitar morrhuanus (4%) Scoletoma (LPIL) (4%) Cossura soyeri (3%) Cerastoderma pinnulatum (2%) Nephtys incisa (2%) Eusarsiella zostericola (2%) Pherusa affinis (1%) Polygordius (LPIL) (1%) Mediomastus (LPIL) (1%) Ninoe nigripes (1%)														

3.4.3 South Reference Area Stations

The grain size distribution at South Reference Area Stations S-8 and S-14 was generally similar; both were dominated by fine sand (>75%), with a moderate proportion of medium sand (10% to 20%) and less than 5% silt-clay (Table 3.4-1). At Station S-4, medium sand was the dominant fraction at slightly more than 50%, followed by a significant fine sand fraction (46%) and less than 3% silt-clay (Table 3.4-1). The combined proportions of coarse sand and gravel were less than 1% at all three stations.

Organism density at the three South Reference Area stations ranged from 2,400 individuals/m² at Station S-8 to 5,625 individuals/m² at Station S-14 (Table 3.4-4). This was generally within the range found at the Red Clay stations but less than that found at the SADMA stations. The number of unique taxa found at each reference station ranged from 28 to 38. The most numerically abundant organisms at the three reference stations were Tubificid oligochaetes, which accounted for 16% of the total overall number of individuals (Table 3.4-4). These are generally considered pollution-tolerant, opportunistic Stage I organisms.

Among the other numerical dominants at the South Reference Area stations were several annelids, including the Stage I polychaetes *Polygordius* sp., *Monticellina dorsobranchialis*, *Exogone hebes*, and *Caulleriella* sp. J, as well as the Stage III polychaetes *Aricidea catherinae* and *Nephtys picta* (Table 3.4-4). Several arthropods were also relatively abundant, including the ostracod *Pellucistoma* sp., the cumacean *Mancocuma stellifera*, the isopod *Chiridotea tuftsi*, the tanaid *Tanaissus psammophilus*, and the amphipods *Rhepoxynius epistomus* and *Unciola* sp. The nut clam *Nucula proxima* was also among the top 15 most abundant taxa, but at significantly lower densities than observed at the Red Clay and SADMA stations (Table 3.4-4).

Shannon-Weiner diversity (H') ranged from 2.53 to 3.23 and Pielou's evenness ranged from 0.76 to 0.89 at the three South Reference Area stations (Table 3.4-4). Reflecting the relatively high number of taxa found at Station S-4, this station had the highest species richness among the three.

3.4.4 Comparison of Red Clay, SADMA, and South Reference Area Stations

3.4.4.1 Univariate Statistics

The average organism density per station at the SADMA stations (19,635 individuals/m²) was higher than at either the Red Clay stations (10,592 individuals/m²) or South Reference Area stations (3,850 individuals/m²; Table 3.4-5). This difference is due largely to the disproportionately high numbers of *Nucula proxima* at several of the SADMA stations. This organism was also relatively abundant at, but distributed unevenly among, the Red Clay stations.

The three stations groups were roughly comparable in terms of the average number of taxa per station (range 32 to 36), but there was a high degree of variability in this parameter among the SADMA and Red Clay stations (Table 3.4-5). Average species richness, evenness and diversity were all lower at the SADMA stations due to the disproportionately high numbers of *Nucula proxima* compared to the Red Clay and South Reference Area stations.

Table 3.4-4.

Summary of Benthic Community Parameters for the Three South Reference Area Stations

	Station		
	S-4	S-8	S-14
No. individuals/m ²	3,525	2,400	5,625
No. of taxa	38	30	28
Shannon-Weiner diversity	3.23	2.93	2.53
Margelef's species richness	4.53	3.73	3.13
Pielou's evenness	0.89	0.86	0.76
Fifteen most abundant taxa for all 3 stations combined (percent of total abundance in parentheses)	Tubificidae (LPIL) (16%) Exogone hebes (LPIL) (10%) Polygordius (LPIL) (8%) Pellucistoma (LPIL) (8%) Nephtys picta (6%) Mancocuma stellifera (4%) Caulleriella sp. J (4%) Aricidea catherinae (3%) Rhexoxynius epistomus (3%) Rhynchocoela (LPIL) (2%) Tanaissus psammophilus (2%) Monticellina dorsobranchialis (2%) Nucula proxima (2%) Unciola (LPIL) (2%) Chiridotea tuftsi (2%)		

Table 3.4-5.

Comparison of Benthic Community Parameters for the SADMA, Red Clay, and South Reference Area Stations

	SADMA Stations	Red Clay Stations	South Reference Area
Number of stations (samples)	5	15	3
Avg. no. individuals/m ² per station (± 1 s.d.)	19,635 ($\pm 7,984$)	10,592 ($\pm 8,994$)	3,850 ($\pm 1,637$)
Avg. no. taxa per station (± 1 s.d.)	36 (± 12)	35 (± 11)	32 (± 5)
Avg. Shannon-Weiner diversity (± 1 s.d.)	1.60 (± 0.62)	2.55 (± 0.32)	2.9 (± 0.4)
Avg. Pielou's evenness (± 1 s.d.)	0.44 (± 0.14)	0.73 (± 0.10)	0.84 (± 0.07)
Avg. Margelef's species richness (± 1 s.d.)	3.58 (± 1.16)	3.80 (± 0.98)	3.80 (± 0.70)

Only six of the fifteen taxa that were numerically dominant at the SADMA stations were also among the fifteen dominants at the Red Clay stations. The list of abundant taxa common to both areas includes: *Nucula proxima*, *Cirratulidae* (LPIL), *Mediomastus* (LPIL), *Pitar morrhuanus*, *Polygordius* (LPIL), and *Levinsenia gracilis*. While these taxa were among the most abundant at both the SADMA and Red Clay stations, they occurred in different relative proportions in each area.

Among the numerically dominant taxa at the South Reference Area stations, only five (*Nucula proxima*, *Polygordius* (LPIL), *Tubificidae* (LPIL), *Pellucistoma* (LPIL) and *Aricidea catherinae*) were also among the dominants at the SADMA stations, and only two (*Nucula proxima* and *Polygordius* (LPIL)) were also among the dominants at the Red Clay stations. In short, a simple comparison of the lists of the fifteen most abundant organisms in the three areas (Red Clay, SADMA, and South Reference) indicates a significant amount of difference, in terms of both taxonomic composition and relative densities.

3.4.4.2 Multivariate Statistics

In the cluster analysis dendrogram, four distinct groups of stations can be discerned at roughly the 42% Bray-Curtis similarity level: Group 1 consisting of all the Red Clay stations except Station 55, Group 2 consisting of all the SADMA stations, Group 3 consisting of Red Clay Station 55, and Group 4 consisting of the three South Reference Area stations (Figure 3.4-1). The 2-dimensional nMDS plot mirrors the results of the cluster analysis: it shows the same basic grouping of the stations (Figure 3.4-2). In essence, both representations indicate that the Red Clay stations (except Station 55) had benthic community structure more similar to each other than to the stations comprising the other two groups (i.e., the SADMA and South Reference Area groups). Likewise, the SADMA stations had community structure more similar to each other than to either the South Reference Area or Red Clay station groups. Red Clay Station 55 was an obvious outlier; it had a relatively depauperate benthic community (in terms of both numbers of taxa and organism density) that was very different from that at any other station.

The results of the ANOSIM test of significance are summarized in Table 3.4-6. The global test of the null hypothesis “no significance difference in benthic community structure among the three station groups” resulted in an R-statistic of 0.71, at a significance level of 0.1%. This value, which resulted in rejection of the null hypothesis, indicates that there was a small amount of overlap but generally different community structure among the three station groups (i.e., Red Clay, SADMA and South Reference Area groups).

Following the global ANOSIM test, a series of pairwise comparisons were made. These tests showed significant differences in benthic community structure between each possible pair of station groups (Table 3.4-6). The strongest differences existed between the South Reference Area stations and each of the other two station groups (R-statistics of 0.96 and 1.0 in Table 3.4-6). This reflects the fact that among the numerical dominants, the South Reference Area had comparatively few taxa in common with either of the other two areas. For example, both the Red Clay and SADMA stations had high densities of the nut clam *Nucula proxima* and several polychaetes (e.g., *Cirratulidae*, *Tharyx acutus*, *Mediomastus*, *Levinsenia gracilis*, *Scoletoma* sp.) that were either not present or present at comparatively low densities at the South Reference Area stations.

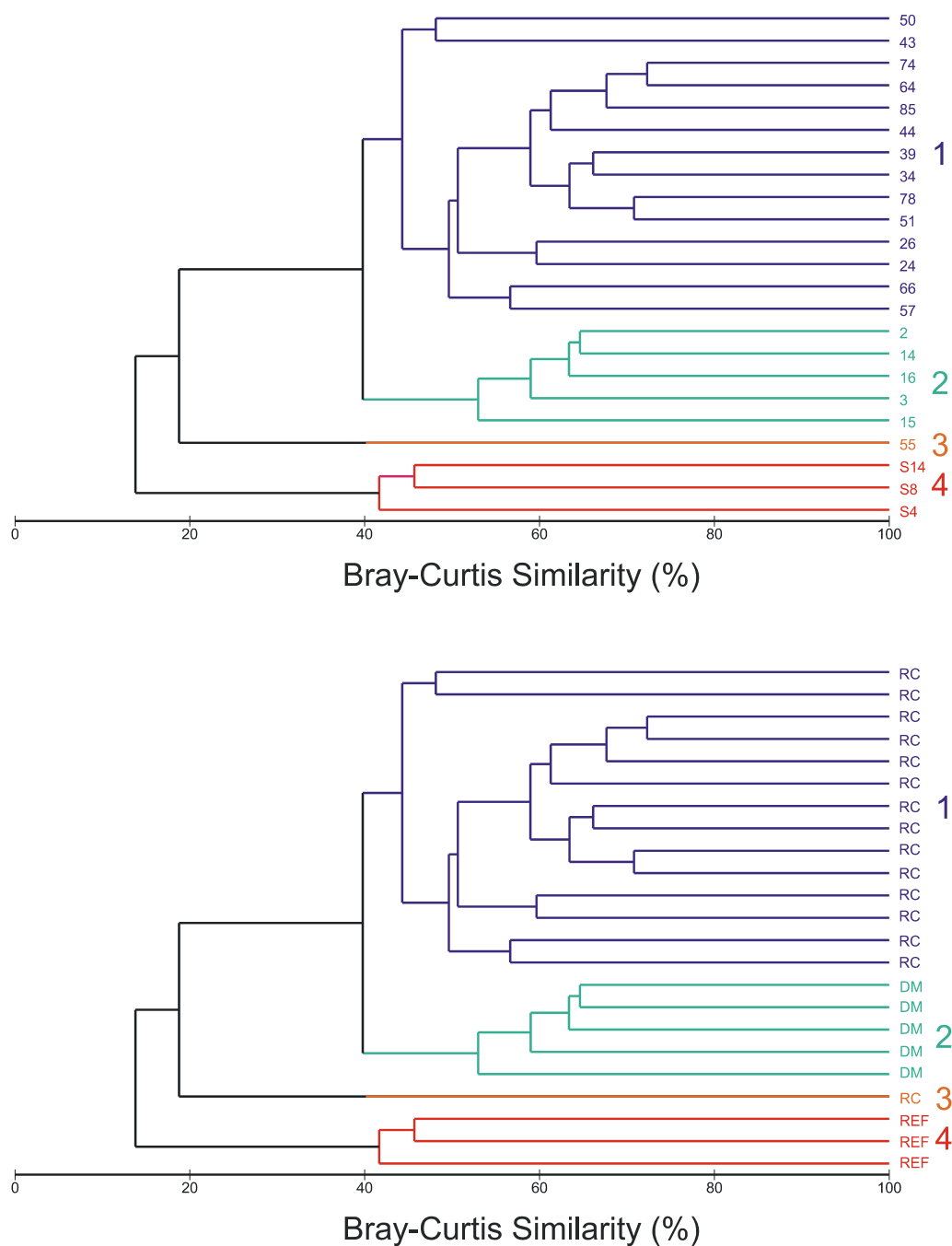


Figure 3.4-1. Dendrograms showing hierarchical clustering of the Red Clay, SADMA, and South Reference Area stations based on Bray-Curtis similarity in benthic community structure. In the original dendrogram (top), different colors show the four station groups that exist at the 42% Bray-Curtis similarity level. The same dendrogram is shown at the bottom, but the station numbers have been replaced with letters indicating the area where each station was located (RC=Red Clay, DM=SADMA, Ref=South Reference Area).

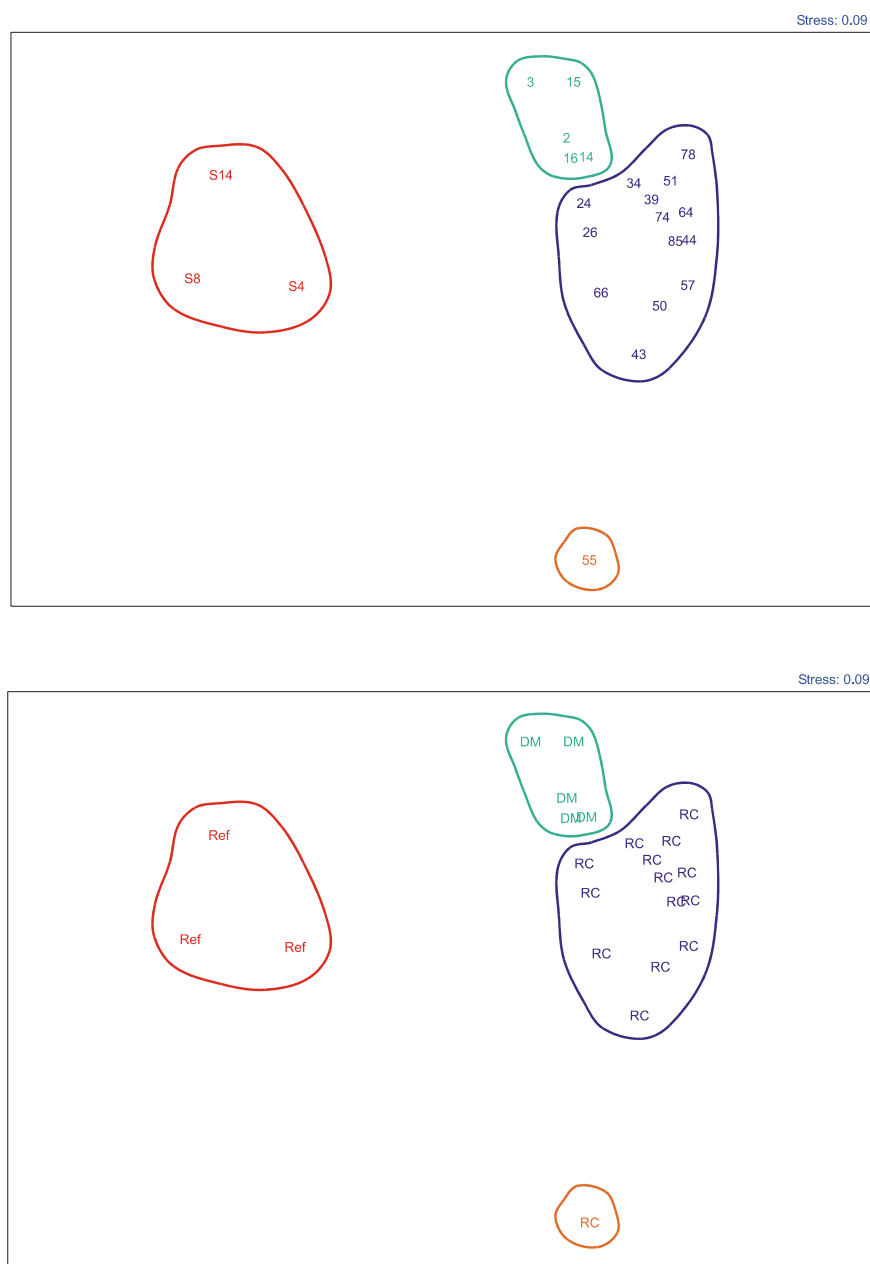


Figure 3.4-2. Two-dimensional nMDS plots of the Red Clay, SADMA, and South Reference Area stations based on Bray-Curtis similarity in benthic community structure. The four station groups from the cluster analysis are circled. The original nMDS plot (top) shows the station numbers. The same nMDS plot is shown at the bottom, but the station numbers have been replaced with letters indicating the area where each station was located (RC=Red Clay, DM=SADMA, Ref=South Reference Area). The stress value of 0.09 indicates there was only a minor and inconsequential amount of distortion in representing the multi-dimensional relationship among stations in this two-dimensional plot.

Table 3.4-6.
 Results of the ANOSIM Test
 (Null Hypothesis = “no significant difference in
 benthic community structure among/between the station groups”)

Test	R-statistic	Significance level (%)	Conclusion ¹
Global test	0.71	0.1	s
Pairwise comparisons:			
Reference stations versus Red Clay stations	0.96	0.1	s
Reference stations versus SADMA stations	1.0	1.8	s
Red Clay versus SADMA stations	0.53	0.2	s

¹ the letter “s” indicates a significant difference exists among/between groups and the null hypothesis is rejected. An R statistics of >0.75 indicates a strong separation or large difference in overall benthic community structure among/between groups, while 0.75>R>0.25 indicates varying degrees of overlap but generally different community structure among/between groups.

The SADMA and Red Clay stations also had significantly different benthic community structure, although the R-statistic of 0.53 indicates a moderate degree of overlap between the two. Although different, the Red Clay and SADMA station groups were more similar to each other than either was to the South Reference Area station group. This is reflected in the distances among these three station groups in the nMDS plot (Figure 3.4-2).

Among the main differences in benthic community structure between the Red Clay and SADMA station groups were the following: 1) the average abundance of *Nucula proxima* was much higher at the SADMA stations (11,215 individuals/m²) compared to the Red Clay stations (3,010 individuals/m²), 2) the polychaetes *Levinsenia gracilis*, *Scoletoma* sp., and *Cossura soyeri* were much more abundant at the Red Clay stations, and 3) several taxa (e.g., *Tharyx acutus*, *Mediomastus* sp., *Tellina agilis*, *Polygordius* sp., *Pita morrhuanus*, and *Tubificidae*) were much more abundant at the SADMA stations.

4.0 DISCUSSION

4.1 Physical Characteristics of the Red Clay

The vibracores obtained at Stations 68 and 76 contained red clay over the full length of each core, indicating that the red clay deposit at these two sampling locations had a thickness of at least 1.58 m (Station 68) and 2.82 m (Station 76). These thickness estimates are conservative, because they are limited to the penetration depth that was achieved by the vibracoring device. The acoustic sub-bottom profiling results provide additional insight, indicating that the red clay deposit in the area where the cores were taken (corresponding to the area of the most intense placement activity, as shown in Figure 1.1-2) had a maximum thickness of about 5 to 7 m (Figure 3.2-2).

The upper 5 to 10 cm of marine sediments is considered the most biologically active zone, and assuming the red clay deposit had a thickness on the order of several meters, it is the condition of its outermost surface or “skin” that will determine the types and numbers of organisms present. It is instructive to compare the conditions found over the surface of the deposit in the present study with those observed in the previous REMOTS survey of October 1998. In this earlier “reconnaissance” survey, conducted one to two years after the red clay had been deposited, the sediment-profile and plan view images showed that intact clumps or chunks of cohesive red clay existed at the sediment surface at a significant number of stations (Figure 4.1-1). Due to the widespread presence of these larger, discrete clay clumps, the surface of the red clay deposit appeared to have considerable small-scale relief or “roughness.” Quantitative boundary roughness measurements were not made as part of the October 1998 REMOTS survey, but surface roughness was described as “medium” or “high” at 56 of the 70 Red Clay stations (80%). Based on these qualitative descriptions, the average small-scale boundary roughness over the red clay deposit is estimated to have been on the order of 3 to 10 cm at the time of the October 1998 survey.

In contrast, the boundary roughness values for the Red Clay stations in the June 2002 survey ranged from 0.4 to 3.2 cm and averaged 1.1 cm (Table 3.3-2), indicating an absence of significant small-scale relief or roughness over the surface of the red clay deposit. In particular, neither the sediment-profile nor plan view images collected in June 2002 showed the widespread presence of the larger, cohesive clumps or chunks of red clay that had been observed in the October 1998 survey. These results strongly suggest that the surface has become smoother over time. The side-scan sonar mosaic from summer 2002 likewise failed to show any significant, increased surface relief or roughness of the seafloor in the areas where the red clay had been deposited (Figure 3.2-1).

The apparent smoothing of the red clay deposit’s surface may be due to a number of “weathering” processes. The continuous washing action of bottom currents might reasonably be expected to wear down and gradually smooth the angular surfaces of the original cohesive clay chunks. In the October 1998 survey, there also were numerous visible holes in the clay chunks attributed to burrowing organisms (e.g., Figure 4.1-1, right image), and such burrowing/tunneling activities would also serve to enhance the breakdown of the clay into finer



Figure 4.1-1. Representative REMOTS sediment-profile images (left and center) and plan view image (right) from the October 1998 survey illustrating cohesive clumps of red clay observed at the surface of the red clay deposits. In the plan view image (right), a crab is seen next to the large clay chunk, and numerous small holes (assumed organism burrows) are visible at the top of the clay chunk.

fragments over time. Furthermore, the images from the June 2002 survey indicated that a surface layer of silty sand was present over the red clay at many stations (e.g., Figures 3.3-6 and 3.3-19). Presumably, over the years, this sand has been transported from surrounding areas by bottom currents. As it has washed over the red clay deposits, it has accumulated in the interstitial spaces among the cohesive clumps. The gradual filling in of these interstitial spaces, combined with the weathering of the clumps by current action and biological reworking, would all result in the observed smoothing of the red clay's surface.

The net effect, from a biological perspective, is that this surface has changed in both form and composition over time. Initially, it was relatively homogenous in composition, consisting of red clay that was either loose (i.e., unconsolidated) or consolidated into larger, cohesive chunks and clumps. The presence of the cohesive chunks resulted in significant small-scale relief or roughness. As the clay has weathered over time, it has become significantly smoother, and both sandy sediments from surrounding areas and organic matter settling out of the overlying water column have accumulated in the spaces among cohesive chunks. Therefore, the sediments comprising the surface of the red clay deposit have become more heterogeneous in texture, as evidenced both from the imaging results and the grain size analyses showing the presence of significant fractions of fine and medium sand mixed with the silt-clay (Table 3.4-1). Coincident with these physical changes that have occurred over the past 5 years, there have been significant changes in biological conditions (described in the following section).

4.2 Benthic Recolonization Status of the Red Clay

Both the sediment-profile and plan view images clearly indicate that the surface of the red clay deposit was inhabited by an active benthic community consisting of both epifaunal and infaunal organisms at the time of the June 2002 survey. Both sets of images showed that the surface of the cohesive clay, as well as rocks and pebbles mixed with the clay, were providing hard surfaces that were serving as attachment points for colonial hydroids and bryozoans (e.g., Figures 3.3-13, 3.3-16, and 3.3-19). Other epifauna observed in the plan view images at the Red Clay stations included starfish and crabs. In addition, Stage II Podocerid amphipods were widespread across the surface of the red clay deposit, as evidenced by the distinctive thin stalks constructed by these organisms to raise themselves a few centimeters above the seafloor to facilitate suspension-feeding (Figures 3.3-11 and 3.3-18). Furthermore, both Stage I polychaete tubes and, to a lesser extent, Stage III feeding voids were visible in the sediment-profile images obtained at the Red Clay stations (Figures 3.3-14 and 3.3-15).

In the October 1998 survey, the benthic infauna observed at both the SADMA and Red Clay stations consisted exclusively of a Stage I community comprised of very small polychaetes and crustaceans living on or at the sediment surface (upper 1 cm). Evidence of Stage III was found at only two of the twenty stations in the SADMA, but it was hypothesized that it was still too soon following the disposal of the organic-rich, fine-grained dredged material in this area (1 to 2 years) for it to be recolonized extensively by Stage III organisms. However, it was anticipated that the infaunal successional process would result in a significant increase in the abundance of Stage III organisms in the coming years.

In the Red Clay Areas, it was hypothesized that the food source for the observed surface-dwelling, Stage I community consisted mainly of organic matter that had settled out of the water column and accumulated in depressions and flat areas among the larger cohesive clay clumps. As a result, this community was assumed to have relatively low diversity and abundance, as well as a patchy distribution among the clay chunks. Mobile epifauna (e.g., crabs and starfish) were observed to be present on the red clay deposits during the October 1998 survey, and it was hypothesized that over time, the burrowing and feeding activities of both the infaunal and epifaunal communities would act to break down the larger cohesive clay clumps and increase the organic carbon content of the red clay's surface. This in turn was expected to result in a gradual increase in the abundance of larger-bodied, Stage III infauna.

The results of the summer 2002 survey appear to verify the accuracy of several of these earlier predictions. As indicated, the surface of the red clay deposit did appear to have become smoother, with notably fewer large, discrete, cohesive clay chunks. In addition, the small depressions and interstitial spaces among the clay chunks were apparently filled with migrating silt and sand. The net effect is that the red clay, in both the sediment-profile and plan view images, appeared much more weathered and was "draped" to a much greater extent with silty sand, organic matter, and associated benthic organisms in 2002 compared to 1998. In terms of epifauna, the summer 2002 images showed that mobile predators like crabs and starfish continued to be present (e.g., Figure 3.3-17), but numerous colonial hydroids not observed previously in October 1998 had become widespread over the surface of the red clay (e.g., Figures 3.3-13 and 3.3-19).

In terms of infauna, the REMOTS results suggest that the anticipated increase in the abundance of Stage III organisms also had occurred. Interestingly, a higher percentage of the replicate sediment-profile images obtained at the Red Clay stations showed evidence of sub-surface, Stage III feeding voids than at the SADMA stations (32% versus 17%), but it is possible that this is simply an artifact of the very unequal sample sizes between the two areas (140 total images obtained at the Red Clay stations versus 12 at the SADMA stations). Nevertheless, the REMOTS results indicate that a relatively diverse infaunal community comprised of abundant Stage I polychaetes and Stage II amphiods at the sediment surface, and larger-bodied Stage III infauna, was widespread across both the SADMA and Red Clay Area during the summer 2002 survey (e.g., Figures 3.3-18 and 3.3-15).

The taxonomic analysis of the benthic community serves to support the REMOTS interpretation. The fifteen most abundant taxa at both the SADMA and Red Clay grab sampling stations included a variety of both Stage I and Stage III polychaetes (e.g., *Cirratulidae*, *Tharyx acutus*, *Mediomastus*, *Levinsenia gracilis*, *Scoletoma*, *Nephtys incisa*), as well as shallow-dwelling Stage II bivalves (most notably the nut clam, *Nucula proxima*). All of these taxa are common in the New York Bight, and most of them are considered to be relatively insensitive to contaminants (Chang et al. 1992). The average organism density (individuals/m²) at the Red Clay stations was somewhat less than that at the SADMA stations, but significantly higher than found in the ambient sandy sediment at the South Reference Area (Table 3.4-5). All three areas had comparable average numbers of taxa, and taxonomic diversity, evenness, and richness values at the Red Clay stations were similar to those at the South Reference Area stations (Table 3.4-5).

It is possible to conclude that as of summer 2002, the red clay deposits had become recolonized by a benthic infaunal community that was both diverse and abundant, but whose overall composition (in terms of the taxa present and their relative numbers) was fundamentally different from the communities found at either the SADMA or South Reference Area. The basic difference in community structure among the three areas (as revealed in the multivariate analyses of Figures 3.4-1 and 3.4-2 and the associated ANOSIM statistical test of Table 3.4-6) is most readily attributed to their different substrates. Specifically, the homogenous fine sand at the South Reference Area represents a benthic habitat fundamentally different from both the fine-grained dredged material at the SADMA and the sand/clay mixtures comprising the surface of the red clay deposits. These differences in habitat type have become manifested in the observed differences in both the types and numbers of resident infauna. From a purely *functional* perspective, however, it is possible to conclude that the Red Clay and SADMA communities were similar: both were composed of diverse mixtures of surface-dwelling Stage I and II suspension-feeders, as well as Stage III deposit-feeders, at the time of the summer 2002 survey.

5.0 CONCLUSIONS

- Sediment vibracores and acoustic sub-bottom profiling data collected during summer 2002 indicated that the red clay deposit created in 1997 in the northeast corner of the former Mud Dump Site had a thickness ranging from 5 to 7 m. Side-scan sonar data revealed an absence of any distinct signatures denoting the presence of this material on the seafloor. In particular, there was a notable lack of any small-scale surface relief or roughness associated with the red clay deposit.
- The sediment-profile and plan view images indicated that the surface of the red clay deposit was much flatter and smoother in summer 2002 than it was in October 1998, with an absence of the larger, cohesive chunks of clay that had been observed in the earlier survey. In addition, a thin veneer of silt, sand, and organic matter had become deposited on the surface of the red clay.
- It is hypothesized that the action of bottom currents and the burrowing activities of larger organisms have acted to break down the larger clay chunks over time. As the clay has weathered and the spaces among clay chunks have become filled with silt and sand, the surface of the deposit has become considerably smoother and more heterogeneous in composition.
- The sediment-profile and plan view images both indicated that the SADMA and Red Clay Area had become recolonized by relatively abundant and diverse infaunal communities consisting of both surface-dwelling (i.e., Stages I and II) and deeper-burrowing (i.e., Stage III) organisms at the time of the summer 2002 survey. The images also indicated that there were numerous sessile and mobile epifauna living on the surface of the red clay, including crabs, starfish, and colonial hydroids.
- Taxonomic analysis of benthic grab samples confirmed the REMOTS successional stage interpretations and indicated relatively high organism abundance at the Red Clay and SADMA stations compared to the South Reference Area stations.
- The benthic communities in the Red Clay, SADMA and South Reference Area differed significantly in terms of both the types and numbers of infauna that were present, reflecting the significant differences that exist in the type of surface sediments occurring in each of these three areas.
- From a functional perspective, the Red Clay and SADMA communities were similar, in that both were composed of diverse mixtures of surface-dwelling Stage I and II suspension-feeders, as well as Stage III deposit-feeders, at the time of the summer 2002 investigation.

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APPENDIX A CORE LOGS

The 2002 Survey of the Red Clay Deposit Area

Survey: HARS Coring 2002

Longitude: -73.83505

Core: RC68


Latitude: 40.39226

Total Core Length: 158 cm

Cap Interface: none



Page 1 of 4

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology
	0	0-9			
	-4				
	-8				
	-12	9-26		9-11	Bulk Density, Water Content
	-16				
	-20				
	-24				
	-28	26-57			
	-32				
	-36				
	-40			37-43	Bulk Density, Grain Size - w/Hydrometer, TOC, Water Content

The 2002 Survey of the Red Clay Deposit Area

Survey: HARS Coring 2002

Longitude: -73.83505

Core: RC68


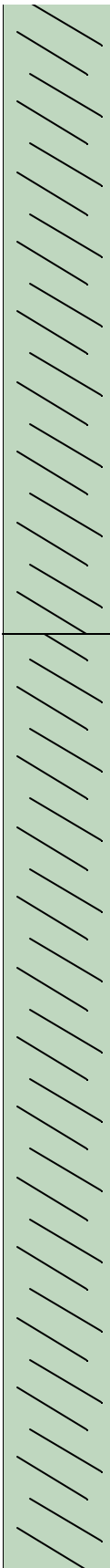
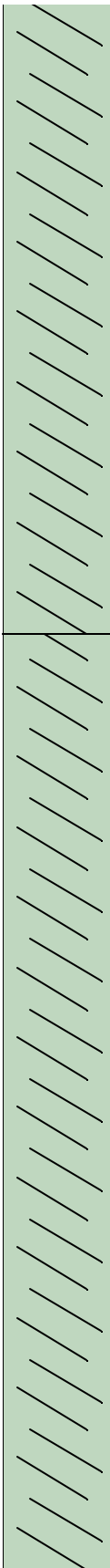
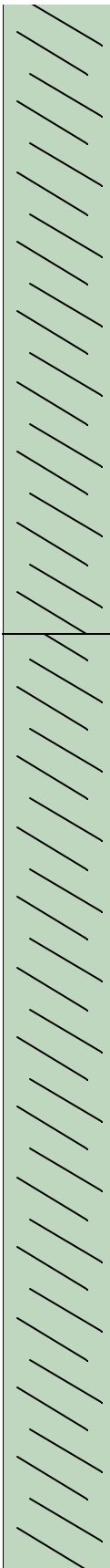
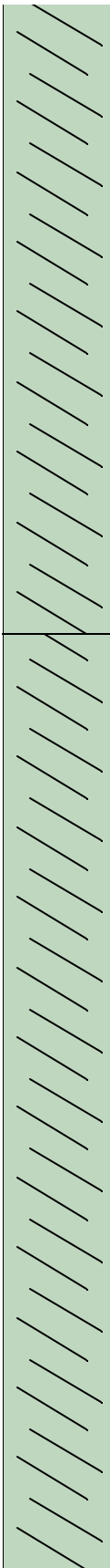
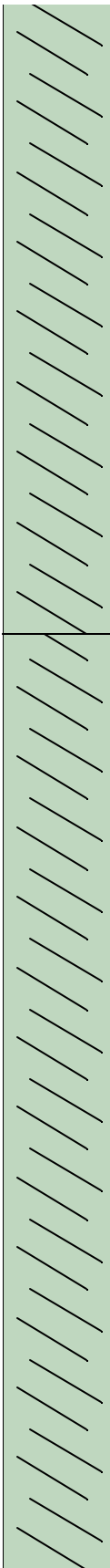
Latitude: 40.39226

Total Core Length: 158 cm

Cap Interface: none



Page 2 of 4

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology
	-44	57-114			
	-48				
	-52	57-114			
	-56				
	-60	57-114			
	-64				
	-68	57-114			
	-72				
	-76	57-114		69-71 Bulk Density, Water Content	
	-80				

red, no odor,
moist, firm-hard,
CLAY

69-71 Bulk Density,
Water Content

The 2002 Survey of the Red Clay Deposit Area

Survey: HARS Coring 2002

Longitude: -73.83505

Core: RC68


Latitude: 40.39226

Total Core Length: 158 cm

Cap Interface: none



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Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology
	-84				
	-88				
	-92				
	-96				
	-100			97-103	Bulk Density, Grain Size - w/Hydrometer, Shear Strength, Specific Gravity, TOC, Water Content
	-104				
	-108				
	-112				
	-116	114-133	red, no odor, moist, firm, Sandy CLAY		
	-120				

The 2002 Survey of the Red Clay Deposit Area

Survey: HARS Coring 2002

Longitude: -73.83505

Core: RC68


Latitude: 40.39226

Total Core Length: 158 cm

Cap Interface: none



Page 4 of 4

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology
	-124				
	-128				
	-132				
	-136	133-147	red, no odor, moist, firm-hard, CLAY		
	-140			137-143	Bulk Density, TOC, Water Content
	-144				
	-148	147-158	red, no odor, moist, soft-firm, Sandy CLAY		
	-152				
	-156				

The 2002 Survey of the Red Clay Deposit Area

Survey: HARS Coring 2002

Longitude: -73.83453

Core: RC76

Latitude: 40.39204

Total Core Length: 282 cm

Cap Interface: none



Page 1 of 4

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology
	0	0-22			
	-4				
	-8				
	-12				
	-16				
	-20				
	-24	22-37			
	-28				
	-32				
	-36				
	-40	37-72			
	-44				
	-48				
	-52				
	-56				
	-60				
	-64				
	-68				

The 2002 Survey of the Red Clay Deposit Area

Survey: HARS Coring 2002

Longitude: -73.83453

Core: RC76


Latitude: 40.39204

Total Core Length: 282 cm

Cap Interface: none



Page 2 of 4

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology
	-72	72-118	red with black, no odor, moist, firm, CLAY	87-93	Bulk Density, Water Content
	-76				
	-80				
	-84				
	-88				
	-92				
	-96				
	-100				
	-104				
	-108				
	-112				
	-116				
	-120	118-178	red, no odor, moist, firm-hard, sandy CLAY		
	-124				
	-128				
	-132				
	-136				
	-140				

The 2002 Survey of the Red Clay Deposit Area

Survey: HARS Coring 2002

Longitude: -73.83453

Core: RC76

Latitude: 40.39204

Total Core Length: 282 cm

Cap Interface: none



Page 3 of 4

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology
	-144				
	-148				
	-152				
	-156				
	-160				
	-164				
	-168				
	-172				
	-176				
	-180	178-282	164-170	147-153	
	-184	red, no odor, moist, hard, CLAY	Rock	Bulk Density, Grain Size - w/Hydrometer, Shear Strength, Specific Gravity, TOC, Water Content	
	-188				
	-192				
	-196		195-201		
	-200		Rock		
	-204				
	-208				

The 2002 Survey of the Red Clay Deposit Area

Survey: HARS Coring 2002

Longitude: -73.83453

Core: RC76


Latitude: 40.39204

Total Core Length: 282 cm

Cap Interface: none



Page 4 of 4

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology
	-212				
	-216				
	-220			217-223	Bulk Density, TOC, Water Content
	-224				
	-228				
	-232				
	-236				
	-240				
	-244				
	-248				
	-252				
	-256				
	-260				
	-264				
	-268				
	-272				
	-276				
	-280				

The 2002 Survey of the Red Clay Deposit Area

Survey: HARS Coring 2002

Longitude: -73.85045

Core: SA2

Latitude: 40.394

Total Core Length: 292 cm

Cap Interface: none



Page 1 of 4

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology
	0	0-22			
	-4				
	-8				
	-12				
	-16				
	-20			19-21	
	-24	22-31		Bulk Density, Water Content	
	-28				
	-32	31-38			
	-36				
	-40	38-44			
	-44				
	-48	44-152	46-48		
	-52		52-64		
	-56				
	-60				
	-64		64-65		
	-68				
	-72		70-71		

The 2002 Survey of the Red Clay Deposit Area

Survey: HARS Coring 2002

Longitude: -73.85045

Core: SA2


Latitude: 40.394

Total Core Length: 292 cm

Cap Interface: none



Page 2 of 4

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology
	-76				
	-80			79-81	Bulk Density, Water Content
	-84				
	-88				
	-92	91-98	shell		
	-96				
	-100				
	-104				
	-108				
	-112				
	-116				
	-120	117-142	mottled greenish-gray clay	117-123	Bulk Density, Grain Size - w/Hydrometer, Shear Strength, Specific Gravity, Water Content
	-124				
	-128				
	-132				
	-136				
	-140				
	-144				

The 2002 Survey of the Red Clay Deposit Area

Survey: HARS Coring 2002

Longitude: -73.85045

Core: SA2


Latitude: 40.394

Total Core Length: 292 cm

Cap Interface: none



Page 3 of 4

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology
	-148				
	-152	152-176			
	-156	black, petroleum odor, wet, very soft, CLAY			
	-160				
	-164				
	-168				
	-172				
	-176	176-198			
	-180	black, petroleum odor, wet, hard, SAND			
	-184				
	-188				
	-192				
	-196				
	-200	198-209			
	-204	black, petroleum odor, wet-moist, soft, CLAY	200-201	197-203 Bulk Density, Water Content	
	-208		shell hash		
	-212	209-238			
	-216	black with mottled gray, petroleum odor, moist-wet, firm, SAND			
	-220				

The 2002 Survey of the Red Clay Deposit Area

Survey: HARS Coring 2002

Longitude: -73.85045

Core: SA2

Latitude: 40.394

Total Core Length: 292 cm

Cap Interface: none



Page 4 of 4

Core Photo	Depth (cm)	Major Interval	Sub-Interval	Analysis	Lithology
	-224				
	-228				
	-232				
	-236				
	-240	238-249		239-241	Bulk Density, Grain Size - w/Hydrometer, Water Content
	-244				
	-248				
	-252	249-292			
	-256		256-261		
	-260				
	-264				
	-268				
	-272				
	-276				
	-280				
	-284				
	-288				
	-292				

APPENDIX B
REMOTS IMAGE ANALYSIS RESULTS

Appendix B1

REMOTS Sediment-Profile Imaging Data from the SADMA Stations, June 2002 Survey

Station	Replicate	Date	Time	Successional	Grain Size (phi)			Benthic Habitat	Mud Clasts		Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Apparent RPD Thickness (cm)			Methane			OSI	Surface Roughness	Low DO	Comments
					Min	Max	Maj Mode		Count	Avg. Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Count	Mean	Diam				
1	A	6/22/2002	09:43	ST I on III	> 4 phi	2 phi	> 4 phi	UN-SF	0	0	11.7	12.52	0.82	12.11	> 11.7	> 12.52	> 12.11	0	0	0	0.07	3.79	1.34	0	0	0	7	Physical	NO	Relic DM>pen, Tan sand/dm, blk sulfidic m, surf reworking, burrows-openings, voids, sm tubes, shell bits
1	B	6/22/2002	09:44	ST I	> 4 phi	2 phi	> 4 phi	UN-SF	2	1.26	13.52	14.88	1.36	14.2	> 13.52	> 14.88	> 14.2	0	0	0	0.07	2.17	0.96	0	0	0	3	Physical	NO	Relic DM>pen, Tan sand/dm, blk sulfidic m, red clasts, sm tubes, thin & patchy RPD, wiper clasts
2	A	6/22/2002	09:51	ST I	> 4 phi	2 phi	3 to 2 phi	UN-SS	0	0	10.81	11.45	0.64	11.13	> 10.81	> 11.45	> 11.13	0	0	0	3.37	6.38	4.58	0	0	0	7	Physical	NO	DM>pen, Tan sand/dm, blk sulfidic m @ z, shell bits, sm tubes; print for report - sand over relic dm layering
2	B	6/22/2002	09:51	ST I	> 4 phi	2 phi	> 4 phi	UN-SF	0	0	9.29	10.4	1.11	9.84	> 9.29	> 10.4	> 9.84	0	0	0	0.70	2.10	1.38	0	0	0	3	Physical	NO	DM>pen, S/M, Tan sand/dm, blk sulfidic m @z, shell bits, sm tubes; print for report - sand over relic dm stratigraphy
3	B	6/23/2002	13:06	ST I	> 4 phi	2 phi	> 4 phi	UN-SI	5	0.26	11	12.18	1.18	11.59	> 11	> 12.18	> 11.59	0	0	0	0.14	3.01	1.72	0	0	0	4	Biogenic	NO	Relic DM>pen, Tan sand/dm, blk sulfidic m, dense hydroids, ox & red clasts, tubes, surf reworking
3	C	6/23/2002	13:19	ST II	> 4 phi	2 phi	> 4 phi	UN-SF	6	0.47	12.04	13.91	0.87	12.48	> 12.04	> 13.91	> 12.48	0	0	0	0.07	1.89	0.90	0	0	0	5	Physical	NO	Relic DM>pen, Tan sand/dm, sulfidic m, red clasts, thin & patchy RPD, silt imp-far, sm tubes, shell bits
14	B	6/23/2002	12:57	ST I	> 4 phi	2 phi	> 4 phi	UN-SF	5	0.21	11.36	13.41	2.05	12.39	> 11.36	> 13.41	> 12.39	0	0	0	0.98	4.07	2.91	0	0	0	5	Physical	NO	Relic DM>pen, Tan sand/dm, blk sulfidic m, wiper clast, ox & red clasts, sm tubes, shell bits, worm @z, burrowing anenome @ z
14	C	6/23/2002	12:58	ST I	> 4 phi	2 phi	> 4 phi	UN-SF	2	0.19	11.4	13.2	1.8	12.3	> 11.4	> 13.2	> 12.3	0	0	0	0.14	2.24	0.81	0	0	0	3	Physical	NO	DM>pen, Tan sand/dm, blk sulfidic m, sand ripple?, ox & red clasts, sm tubes, shell bits, sm void?, thin RPD
15	A	6/23/2002	12:52	ST I	> 4 phi	2 phi	> 4 phi	UN-SF	0	0	12.9	13.86	0.96	13.38	> 12.9	> 13.86	> 13.38	0	0	0	0.56	4.49	1.88	0	0	0	4	Physical	NO	Relic DM>pen, Tan sand/dm, blk sulfidic m, sm tubes, shell bits, surf reworking, expelled sed-camera artifact
15	C	6/23/2002	12:53	ST I on III	> 4 phi	2 phi	> 4 phi	UN-SF	4	0.18	12.4	13.22	0.82	12.81	> 12.4	> 13.22	> 12.81	0	0	0	0.21	2.38	1.47	0	0	0	7	Physical	NO	Relic DM>pen, Tan sand/dm, blk sulfidic m, patchy RPD, shell bits, Nucula, surf reworking, fecal lyr or camera artifact, ox clasts, burrow
16	A	6/23/2002	12:46	ST I	> 4 phi	2 phi	> 4 phi	UN-SI	0	0	11.52	12.77	1.25	12.15	> 11.52	> 12.77	> 12.15	0	0	0	2.10	3.79	2.71	0	0	0	5	Physical	NO	Relic DM>pen, Tan sand/dm, blk sulfidic m, shell bits, sand ripple, sm tubes, worm @z, possible Nucula?
16	C	6/23/2002	12:47	ST I	> 4 phi	3 phi	> 4 phi	UN-SI	0	0	11.86	12.45	0.59	12.15	> 11.86	> 12.45	> 12.15	0	0	0	0.07	2.10	0.85	0	0	0	3	Physical	NO	Relic DM>pen, Tan sand/dm, blk sulfidic m, thin RPD, expelled sed-camera artifact, shell frags, surf reworking, burrows, voids @ bottom?

Appendix B2

REMOTS Sediment-Profile Imaging Data from the Red Clay Deposit, June 2002 Survey

Station	Replicate	Date	Time	Successional	Grain Size (phi)			Benthic Habitat	Mud Clasts			Camera Penetration (cm)			Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Apparent RPD Thickness (cm)			Methane		OSI	Surface Roughness	Low DO	Comments		
					Min	Max	Major Mode		Count	Avg	Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Count					Mean	Diam
21	B	6/23/2002	10:21	ST I	> 4 phi	2 phi	3 to 2 phi	SA F	0	0	0	0	9.38	10.24	0.88	9.8	0	0	0	0	0	1.19	8.13	8.20	0	0	7	Physical	NO	Tan fine sand-pen, dm?, gastropod @ surf, RPD pen?, sand ripples	
21	C	6/23/2002	10:22	ST II	> 4 phi	2 phi	3 to 2 phi	SA F	0	0	0	0	9.79	10.66	0.87	10.23	0	0	0	0	0	2.17	5.19	3.75	0	0	8	Physical	NO	Tan & gray fine sand-pen, dm?, stick amps, shell bits	
22	A	6/23/2002	10:27	ST I on III	> 4 phi	3 phi	> 4 phi	UN SF	0	0	0	0	9.88	11.63	1.75	10.76	> 9.88	> 11.63	> 10.76	0	0	0	0.35	4.28	2.52	0	0	9	Physical	NO	Tan fine sand mixed w/ red clay-pen, red pebbles @ surf, tubes, burrows, voids, red sed patches@z, biogenic mound-far?
22	B	6/23/2002	10:28	ST I	> 4 phi	3 phi	> 4 phi	UN SF	0	0	0	0	5.15	6.68	1.53	5.91	> 5.15	> 6.68	> 5.91	0	0	0	0.07	3.01	1.84	0	0	5	Physical	NO	Red clay-pen, red clay clumps @ surf, stick amp-far?, burrow opening-r?
23	B	6/23/2002	10:17	ST I	> 4 phi	0 phi	> 4 phi	UN SI	0	0	0	0	8.24	9.25	1.01	8.74	> 8.24	> 9.25	> 8.74	0	0	0	0.28	4.35	2.40	0	0	9	Physical	NO	DM-pen, Bm fine sand mixed w/ red clay & silt, red pebbles@surf, tubes, shell bits, worm @z
23	C	6/23/2002	10:17	ST I	> 4 phi	2 phi	> 4 phi	UN SI	0	0	0	0	3.2	6.04	2.84	4.62	> 3.2	> 6.04	> 4.62	0	0	0	0.07	5.82	2.55	0	0	5	Biogenic	NO	DM-pen, Bm sand/silt silt, lg rock @ surf w/ dense hydroids, red sed @z
24	A	6/23/2002	11:00	ST I	> 4 phi	3 phi	> 4 phi	UN SI	0	0	0	0	7.15	8	0.85	7.57	> 7.15	> 8	> 7.57	0	0	0	0.63	3.37	2.37	0	0	5	Biogenic	NO	Bm fine sand mixed w/ red clay-pen, lg red rock @ surf, dense hydroids, m clumps-far, fecal/lock lyr, tubes, worm @z
24	B	6/23/2002	11:01	ST I	> 4 phi	3 phi	> 4 phi	UN SI	0	0	0	0	3.9	4.99	1.09	4.44	> 3.9	> 4.99	> 4.44	0	0	0	0.56	3.86	2.71	0	0	5	Physical	NO	Bm fine sand mixed w/ red clay-pen, lg rock @ surf, hydroids, tubes, fecal/lock lyr
25	A	6/23/2002	11:03	ST II	> 4 phi	3 phi	> 4 phi	UN SI	0	0	0	0	10.53	11.13	0.59	10.84	> 10.53	> 11.13	> 10.84	0	0	0	0.70	4.98	3.62	0	0	8	Biogenic	NO	Bm fine sand mixed w/ red clay-pen, stick amps, poly tubes, biogenic mound?
25	B	6/23/2002	11:04	ST I	> 4 phi	3 phi	> 4 phi	UN SI	0	0	0	0	8.99	9.25	0.26	9.12	> 8.99	> 9.25	> 9.12	0	0	0	0.21	4.63	2.73	0	0	5	Biogenic	NO	Red clay-pen, red pebbles @ surf, hydroids, worm @z, burrow, fecal lyrmound?
26	B	6/23/2002	10:33	ST I	> 4 phi	2 phi	4 to 3 phi	UN SS	0	0	0	0	3.31	4.52	1.21	3.91	> 3.31	> 4.52	> 3.91	0	0	0	0.49	3.58	2.48	0	0	5	Physical	NO	Tan & gray sandy m w/ red clay-pen, red pebbles @ surf, tubes
26	C	6/23/2002	10:34	ST I on III	> 4 phi	3 phi	> 4 phi	UN SI	0	0	0	0	4.24	7.45	3.21	5.84	> 4.24	> 7.45	> 5.84	0	0	0	0	0	0	0	0	9	Biogenic	NO	Sandy red clay-pen, red pebbles @ surf, burrow opening, tubes, void? hydroids-far
27	A	6/23/2002	10:36	ST I on III	> 4 phi	2 phi	> 4 phi	UN SI	0	0	0	0	8.09	8.47	0.38	8.28	> 8.09	> 8.47	> 8.28	0	0	0	0.70	4.70	3.69	0	0	10	Physical	NO	Fine sand mixed w/ red clay-pen, red sed patch @z, tubes, sm red clay chips @surf, print for report - physical variability of red clay - mixed with sand and red sed patch
27	B	6/23/2002	10:37	ST II	> 4 phi	3 phi	> 4 phi	UN SI	0	0	0	0	11.66	12.68	1.02	12.17	> 11.66	> 12.68	> 12.17	0	0	0	0.14	3.51	2.19	0	0	6	Physical	NO	Fine sand mixed w/ red clay-pen, red sed patch@z, stick amps, tubes, m clasts-far, burrow? print for report - dense surface tube on sand over red clay
28	A	6/23/2002	10:02	ST I	> 4 phi	2 phi	4 to 3 phi	UN SS	0	0	0	0	5	5.81	0.81	5.4	> 5	> 5.81	> 5.4	0	0	0	0.35	3.37	2.48	0	0	5	Physical	NO	Fine sand mixed wired clay-pen, red pebbles @ surf, sand ripples-far, print for report - sand over red clay
28	B	6/23/2002	10:03	ST II	> 4 phi	< 1 phi	3 to 2 phi	UN SS	0	0	0	0	6.66	9.43	2.77	8.05	> 6.66	> 9.43	> 8.05	0	0	0	0.28	5.05	2.83	0	0	7	Physical	NO	DM-pen, Fine-medium sand mixed wired clay, red pebbles or brick frags @ surf, lg rock @ surf, tubes, stick amp, shell frags
29	A	6/23/2002	10:45	ST I on III	> 4 phi	1 phi	2 to 1 phi	UN SS	0	0	0	0	6.97	10.63	0.66	10.3	> 6.97	> 10.63	> 10.3	0	0	0	1.89	5.61	4.27	0	0	9	Physical	NO	DM-pen, Fine-medium sand mixed w/ red clay, red pebbles or brick frags @ surf, stick amps, shell frags, tubes
30	A	6/23/2002	10:48	ST I	> 4 phi	3 phi	> 4 phi	UN SF	0	0	0	0	4	5.06	1.06	4.53	> 4	> 5.06	> 4.53	0	0	0	-99.00	-99.00	-99.00	0	0	99	Physical	NO	Medium-coarse sand mixed w/ red clay, lg clay clump or big shell @ surf w/ dense hydroids, stick amp, red clast, voids, shell hash
30	C	6/23/2002	10:50	ST I on III	> 4 phi	3 phi	> 4 phi	UN SI	1	0.84	0	0	8.97	10.07	1.1	9.52	> 8.97	> 10.07	> 9.52	0	0	0	0.27	2.80	1.95	0	0	6	Physical	NO	Fine sand mixed w/ red clay-pen, tubes, hydroid, or clast, void low right, snail @ surf, surf rework
31	C	6/22/2002	11:11	ST I	> 4 phi	3 phi	> 4 phi	UN SI	0	0	0	0	4.74	5.97	1.23	5.35	> 4.74	> 5.97	> 5.35	0	0	0	0.88	4.41	3.05	0	0	6	Physical	NO	Sandy m mixed w/ red clay-pen, dense surf tubes
31	B	6/22/2002	11:11	ST I	> 4 phi	2 phi	> 4 phi	UN SI	0	0	0	0	6.54	7.29	0.75	6.91	> 6.54	> 7.29	> 6.91	0	0	0	0.07	5.19	1.20	0	0	3	Physical	NO	Bm/bk sandy m-pen, some red clay, red sed @z, dense surf tubes, red clay chips @ surf
32	A	6/22/2002	11:15	ST I	> 4 phi	3 phi	> 4 phi	UN SF	0	0	0	0	5.95	7.57	1.62	6.76	> 5.95	> 7.57	> 6.76	0	0	0	-99.00	-99.00	-99.00	0	0	99	Physical	NO	Red clay-pen, sm red clay chips @z, red sed patches@z, sm tubes, surface sand layer
32	B	6/22/2002	11:15	ST I	> 4 phi	3 phi	> 4 phi	UN SF	0	0	0	0	4.16	5.49	1.32	4.82	> 4.16	> 5.49	> 4.82	0	0	0	0.27	8.7	5.19	0	0	99	Physical	NO	Sandy m mixed w/ red clay-pen, red clay chips @z, sm tubes, surface sand layer
33	B	6/22/2002	12:08	ST I	> 4 phi	3 phi	> 4 phi	UN SF	0	0	0	0	9.56	9.86	0.3	9.71	> 9.56	> 9.86	> 9.71	0	0	0	-99.00	-99.00	-99.00	0	0	99	Physical	NO	Red clay-pen, tubes, stick amps-far?, surf reworking, flock lyr, red clay chips @z, burrows
33	D	6/23/2002	15:44	ST I	> 4 phi	2 phi	> 4 phi	UN SI	0	0	0	0	10.91	11.45	0.54	11.18	> 10.91	> 11.45	> 11.18	0	0	0	0.21	4.42	2.60	0	0	7	Biogenic	NO	Sand mixed w/ red clay-pen, red clay chips @ surf, red sed streaks, dense poly tubes, stick amps, org @z, 27, 30
34	A	6/22/2002	12:17	ST II	> 4 phi	2 phi	> 4 phi	UN SI	0	0	0	0	5.27	6.56	1.29	5.91	> 5.27	> 6.56	> 5.91	0	0	0	-99.00	-99.00	-99.00	0	0	99	Physical	NO	Print for report - dense surface tubes in sand over red clay
34	C	6/22/2002	12:19	ST I	> 4 phi	2 phi	> 4 phi	UN SI	0	0	0	0	7.84	8.81	0.97	8.33	> 7.84	> 8.81	> 8.33	0	0	0	-99.00	-99.00	-99.00	0	0	99	Physical	NO	Sandy m mixed w/ red clay-pen, red sed patch @z, dense tubes, stick amps, voids or burrow?
35	D	6/22/2002	14:57	ST I	> 4 phi	3 phi	> 4 phi	UN SF	0	0	0	0	8	9.25	1.25	8.62	> 8	> 9.25	> 8.62	0	0	0	1.40	4.63	3.59	0	0	6	Physical	NO	Red clay-pen, red sed patches @z, z, tubes, lg worms @z, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100
35	E	6/22/2002	14:58	ST I	> 4 phi	3 phi	> 4 phi	UN SF	0	0	0	0	6.49	11.59	5.1	9.04	> 6.49	> 11.59	> 9.04	0	0	0	1.40	6.03	4.26	0	0	7	Physical	NO	Red clay-pen, red clay clumps far, tubes, burrow opening?
36	C	6/22/2002	14:39	INDET	> 4 phi	3 phi	> 4 phi	UN SF	0	0	0	0	4.04	5.04	1	4.54	> 4.04	> 5.04	> 4.54	0	0	0	-99.00	-99.00	-99.00	0	0	99	Physical	NO	Red clay-pen, red clasts, RPD measurable?
37	A	6/22/2002	14:39	INDET	> 4 phi	3 phi	> 4 phi	UN SF	0	0	0	0	2.04	3.18	1.14	2.61	> 2.04	> 3.18	> 2.61	0	0	0	-99.00	-99.00	-99.00	0	0	99	Physical	NO	Red Clay-pen, some surface sand, underpen, red clay clumps @ surf, tubes
37	B	6/22/2002	16:10	ST II	> 4 phi	3 phi	> 4 phi	UN SF	1	0.51	0	0	5.72	6.45	0.73	6.09	> 5.72	> 6.45	> 6.09	0	0	0	0.07	4.00	2.46	0	0	7	Physical	NO	Mud mixed w/ red clay-pen, red stick amp @z, red clast, fecal layer
37	C	6/22/2002	16:11	ST II	> 4 phi	2 phi	> 4 phi	UN SF	0	0	0	0	4.52	5.71	1.19	5.14	> 4.52	> 5.71	> 5.14	0	0	0	0.14	3.61	1.38	0	0	3	Physical	NO	Red clay-pen w/ red clay-pen, red stick amp @z, burrow opening, fecal mound?
38	D	6/23/2002	14:06	ST II	> 4 phi	2 phi	3 to 2 phi	UN SS	0	0	0	0	6.59	8.24	1.65	7.41	> 6.59	> 8.24	> 7.41	0	0	0	0.27	5.69	3.35	0	0	6	Physical	NO	Sand mixed w/ red clay-pen, red sed patch @z, z surface shell hash and sand layer over red clay, tubes, stick amps, burrow opening?
38	F	6/23/2002	14:08	ST I on III	> 4 phi	2 phi	> 4 phi	UN SI	0	0	0	0	5.9	7.29	1.39	6.6	> 5.9	> 7.29	> 6.6	0	0	0	0.07	2.17	0.85	0	0	7	Biogenic	NO	print for report - sand shell hash layer with dense tubes over red clay
39	A	6/22/2002	11:57	ST II	> 4 phi	2 phi	4 to 3 phi	UN SS	3	0.43	0	0	4.59	5.45	0.86	5.02	> 4.59	> 5.45	> 5.02	0	0	0	0.21	3.23	1.95	0	0	6	Physical	NO	Sand mixed w/ red clay-pen, red clay chips @z, z, tubes, stick amps, red clasts, shell frags, brick frags
39	C	6/22/2002	11:58	ST I	> 4 phi	2 phi	4 to 3 phi	UN SS	2	0.31	0	0	6.49	7.57	1.08	7.03	> 6.49	> 7.57	> 7.03	0	0	0	-99.00	-99.00	-99.00	0	0	99	Physical	NO	Sand mixed w/ red clay-pen, shell frags, tubes, z, tubes, burrow opening?, surf rework
40	A	6/22/2002	09:52	ST I on III	> 4 phi	2 phi	> 4 phi	UN SF	0	0	0	0	8.02	8.77	0.75	8.4	> 8.02	> 8.77	> 8.4	0	0	0	-99.00	-99.00	-99.00	0	0	99	Physical	NO	Red clay-pen, Fine sand/red Clay, voids, vertical burrow, sm tubes, biogenic mound?
40	B	6/23/2002	09:53	ST I	> 4 phi	2 phi	> 4 phi	UN SF	1	0.42	0	0	4.59	5.27	0.68	4.93	> 4.59	> 5.27	> 4.93	0	0	0	1.40	2.80	2.43	0	0	5	Physical	NO	Print for report - good example of burrow/voids in red clay with surface sand layer
41	B	6/22/2002	12:42	ST I	> 4 phi	2 phi	> 4 phi	UN SI	0	0	0	0	3.41	4.38	0.97	3.89	> 3.41	> 4.38	> 3.89	0	0	0	0.40	3.37	2.35	0	0	5	Biogenic	NO	Red clay-pen, red clast, hydroids-far, red sed @z, worm @z, surf rework
41	C	6/22/2002	12:42	ST I	> 4 phi	3 phi	> 4 phi	UN SS	4	0.82	0	0	3.68	4.82	1.14	4.25	> 3.68	> 4.82	> 4.25	0	0	0	-99.00	-99.00	-99.00	0	0	99	Physical	NO	Red clay-pen, red clay clumps @ surf, dense tubes, surf rework; print for report - dense surface tubes
42	A	6/22/2002	13:42	ST I on III	> 4 phi	2 phi	> 4 phi	UN SF	0	0	0	0	4.91	5.66	0.75	5.28	> 4.91														

Appendix B2 (continued)

REMOTS Sediment-Profile Imaging Data from the Red Clay Deposit, June 2002 Survey

Station	Replicate	Date	Time	Successional	Grain Size (phi)			Benthic Habitat	Mud Clasts Count	Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Apparent RPD Thickness (cm)			Methane			OSI	Surface Roughness	Low DO	Comments	
					Min	Max	Maj Mode			Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Count	Mean	Diam					
71	C	6/22/2002	13:33	ST II	> 4 phi	3 phi	> 4 phi	UN.SI	0	0	6.09	7.07	0.98	6.58	> 6.09	> 7.07	> 6.58	0	0	0	0.49	3.44	2.60	0	0	0	7	Physical	NO	Sandy m mixed w/ red clay>pen, surf reworking, tubes, stick amps, sm worms @z
71	D	6/23/2002	15:22	ST II	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	10.61	13	2.39	11.61	> 10.61	> 13	> 11.61	0	0	0	0.56	4.07	1.98	0	0	0	6	Physical	NO	Sand mixed w/ red clay>pen, tubes, stick amps, shell frags
72	A	6/22/2002	13:51	ST I on III	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	6.54	7.72	1.18	7.13	> 6.54	> 7.72	> 7.13	0	0	0	0.42	3.01	1.51	0	0	0	8	Physical	NO	Mud mixed w/ red clay>pen, red clay chips @ surf, stick amps, tubes, red sed @z, voids, surf rework
72	C	6/22/2002	13:52	ST II	> 4 phi	2 phi	> 4 phi	UN.SI	2	0.23	7.66	8.56	0.9	8.11	> 7.66	> 8.56	> 8.11	0	0	0	0.07	3.37	1.68	0	0	0	6	Biogenic	NO	Red clay>pen, reduced@z, tubes, stick stick amps, red clasts
73	C	6/22/2002	10:05	ST II	> 4 phi	2 phi	3 to 2 phi	SA.F	0	0	5.04	5.52	0.48	5.28	0	0	0	0	0	0	3.15	5.54	5.27	0	0	0	9	Physical	NO	Ambient sand >pen, red clay = camera artifact-amear, sand ripples-far, stick amp
73	E	6/23/2002	13:58	ST I	> 4 phi	3 phi	> 4 phi	UN.SI	0	0	8.41	9.36	0.95	8.89	> 8.41	> 9.36	> 8.89	0	0	0	0.28	4.70	2.57	0	0	0	5	Physical	NO	Sandy m mixed w/ red clay>pen, tubes, red sed @z, surface tubes
74	A	6/22/2002	10:19	ST I to II	> 4 phi	2 phi	> 4 phi	UN.SS	0	0	3.11	4.74	1.63	3.92	> 3.11	> 4.74	> 3.92	0	0	0	0.07	3.44	1.90	0	0	0	5	Physical	NO	Muddy sand mixed w/ red clay>pen, red pebbles @ surf, tubes, stick amps?, shell frags, sand ripple?
74	B	6/22/2002	10:20	ST I	> 4 phi	2 phi	4 to 3 phi	UN.SS	0	0	3.31	3.75	0.44	3.53	> 3.31	> 3.75	> 3.53	0	0	0	0.28	2.94	2.04	0	0	0	4	Physical	NO	Sand/DM, red clay chips @ surf, shell bits, red sed @z, tubes
75	A	6/22/2002	12:31	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	3.22	4.32	1.1	3.77	> 3.22	> 4.32	> 3.77	0	0	0	0.77	2.94	2.05	0	0	0	4	Physical	NO	Muddy sand mixed w/ red clay>pen, red sed @z, tubes
75	B	6/22/2002	12:32	ST II	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	4.18	4.93	0.75	4.55	> 4.18	> 4.93	> 4.55	0	0	0	1.19	3.65	3.05	0	0	0	8	Physical	NO	Muddy sand mixed w/red clay>pen, shell frags, stick amp, tubes
76	D	6/23/2002	15:30	ST I on III	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	12.31	13.04	0.73	12.68	> 12.31	> 13.04	> 12.68	0	0	0	0.07	4.49	1.58	0	0	0	8	Physical	NO	Red clay>pen, sm tubes, burrow, sm voids
76	E	6/23/2002	15:31	ST I	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	10.41	11.5	1.09	10.95	> 10.41	> 11.5	> 10.95	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO	Red clay>pen, red clay clumps @ surf, tubes
77	A	6/22/2002	13:21	ST I on III	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	6.41	7.07	0.66	6.74	> 6.41	> 7.07	> 6.74	0	0	0	0.21	2.10	1.34	0	0	0	7	Physical	NO	Red clay>pen, reduced@z, red clay clump @ surf, dense stick amps, void, tubes, shell bits, print for report - dense stick amps
77	B	6/22/2002	13:28	ST II	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	5.13	6.29	1.16	5.71	> 5.13	> 6.29	> 5.71	0	0	0	0.91	3.65	2.34	0	0	0	7	Biogenic	NO	Sand/DM, red pebbles @ surf, no obvious red clay, dense stick amps, red sed @z, sm worms @z, tubes, org detritus?, fecal mound
78	A	6/22/2002	14:15	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	6.54	8.22	1.68	7.38	> 6.54	> 8.22	> 7.38	0	0	0	1.33	3.51	2.42	0	0	0	5	Physical	NO	Sandy mud mixed w/ red clay >pen, Nucula?, surface tubes
78	B	6/22/2002	14:20	ST I	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	5.13	6.45	1.32	5.79	> 5.13	> 6.45	> 5.79	0	0	0	0.63	3.79	2.32	0	0	0	5	Physical	NO	Sandy m mixed w/ red clay>pen, tubes, hydroids, shell bits, red sed @z, surf reworking
79	D	6/23/2002	14:46	ST I	> 4 phi	3 phi	> 4 phi	UN.SF	1	0.3	14.18	14.95	0.77	14.57	> 14.18	> 14.95	> 14.57	0	0	0	0.14	4.84	2.57	0	0	0	5	Physical	NO	Mud mixed w/ red clay>pen, surf rework, tubes, ox clast, sm worm @z, shell bits
79	E	6/23/2002	14:47	ST II on III	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	13.41	14.36	0.95	13.89	> 13.41	> 14.36	> 13.89	0	0	0	0.07	3.30	1.49	0	0	0	7	Physical	NO	Mud mixed w/ red clay>pen, tubes, stick amps, sm void, surf reworking, fecal lyr?
80	A	6/22/2002	16:18	ST II	> 4 phi	2 phi	4 to 3 phi	UN.SS	0	0	4.18	4.86	0.68	4.52	> 4.18	> 4.86	> 4.52	0	0	0	0.42	3.08	1.42	0	0	0	5	Physical	NO	DM>pen, Muddy sand>pen, no visible red clay, stick amps, tubes, sm void?, org detritus
80	B	6/22/2002	16:19	ST I on III	> 4 phi	3 phi	> 4 phi	UN.SF	5	1.56	6.25	8.15	1.9	7.2	> 6.25	> 8.15	> 7.2	0	0	0	0.07	4.42	0.95	0	0	0	7	Physical	NO	Relic DM>pen, Sandy m >pen, thin RPD, no visible red clay, red clasts, tubes, sm voids, red sed @z
81	A	6/23/2002	12:10	ST II	> 4 phi	2 phi	4 to 3 phi	UN.SS	0	0	8.11	8.54	0.43	8.32	> 8.11	> 8.54	> 8.32	0	0	0	0.07	5.26	3.12	0	0	0	8	Biogenic	NO	DM>pen, Tanigry sandy m, no visible red clay, tubes, stick amps, biogenic mound-far, worm @z, burrow
81	B	6/23/2002	12:10	ST I	> 4 phi	3 phi	> 4 phi	UN.SI	0	0	12.52	13.2	0.68	12.86	> 12.52	> 13.2	> 12.86	0	0	0	0.14	3.15	2.19	0	0	0	4	Physical	NO	DM>pen, Sandy m mixed w/ red clay>pen, red pebbles @ surf, dense stick amps, burrow opening, red sed patch @z, sm voids, poly tubes:: print for report - dense stick amps over Stage III voids and burrow
82	B	6/23/2002	12:01	ST II on III	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	8.63	9.79	1.16	9.21	> 8.63	> 9.79	> 9.21	0	0	0	0.35	3.79	2.52	0	0	0	9	Biogenic	NO	Sandy m mixed w/ red clay>pen, red pebbles @ surf, dense stick amps, burrow opening, red sed patch @z, sm voids, poly tubes:: print for report - dense stick amps over Stage III voids and burrow
82	C	6/23/2002	12:02	ST II	> 4 phi	3 phi	> 4 phi	UN.SI	2	0.65	5.34	7.27	1.93	6.31	> 5.34	> 7.27	> 6.31	0	0	0	0.07	3.23	1.76	0	0	0	6	Physical	NO	Red clay>pen, red pebbles and rocks @surf, rock or ly clay clump-far, stick amp, burrow opening??, red clasts
83	A	6/23/2002	11:56	ST I	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	11.04	12.07	1.03	11.56	> 11.04	> 12.07	> 11.56	0	0	0	0.35	3.30	2.62	0	0	0	5	Physical	NO	Red clay>pen, hydroids, poly tubes, surf reworking, biogenic mound?
83	B	6/23/2002	11:57	ST I	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	11.4	12.11	0.71	11.75	> 11.4	> 12.11	> 11.75	0	0	0	0.21	2.52	1.69	0	0	0	4	Biogenic	NO	Red clay>pen, red pebbles @ surf, dense hydroids, stick amp?, surf reworking, tubes
84	A	6/23/2002	11:52	ST II	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	10.77	11.56	0.79	11.17	> 10.77	> 11.56	> 11.17	0	0	0	0.14	2.94	2.05	0	0	0	6	Biogenic	NO	Sandy m mixed w/ red clay>pen, stick amps, poly tubes, red clay clumps-far, worm @z
84	B	6/23/2002	11:53	ST I on III	> 4 phi	2 phi	> 4 phi	UN.SI	2	0.35	13.06	13.93	0.87	13.5	> 13.06	> 13.93	> 13.5	0	0	0	0.66	4.14	2.61	0	0	0	9	Physical	NO	Sandy m mixed w/ red clay>pen, red clay clumps-far, ox clasts, sm tubes, void, burrow
85	A	6/23/2002	11:50	ST II	> 4 phi	3 phi	> 4 phi	UN.SI	0	0	12.16	13.11	0.95	12.64	> 12.16	> 13.11	> 12.64	0	0	0	0.28	3.65	1.83	0	0	0	6	Physical	NO	Sandy m mixed w/ red clay>pen, red sed @z, poly tubes, stick amp
85	C	6/23/2002	11:50	ST I	> 4 phi	3 phi	> 4 phi	UN.SI	0	0	4.75	5.13	0.38	4.94	> 4.75	> 5.13	> 4.94	0	0	0	0.35	3.30	2.08	0	0	0	4	Physical	NO	Sand mixed w/ red clay>pen, red clay clumps @ surf, hydroids, rock @ surf, stick amp-far?
86	A	6/23/2002	11:18	ST II	> 4 phi	2 phi	> 4 phi	UN.SF	1	0.34	13.22	13.74	0.52	13.48	> 13.22	> 13.74	> 13.48	0	0	0	1.33	4.00	2.73	0	0	0	7	Biogenic	NO	Red clay>pen, reduced @ depth, dense stick amps, poly tubes, ox clast, hydroids, fecal lyr, surf rework
86	B	6/23/2002	11:18	ST II	> 4 phi	3 phi	> 4 phi	UN.SI	0	0	8	9.04	1.04	8.52	> 8	> 9.04	> 8.52	0	0	0	0.14	1.89	0.98	0	0	0	5	Physical	NO	Red clay>pen, stick amps, wiper clast, vertical burrow, poly tubes, patchy RPD, print for report - vertical burrow and stick amps
87	A	6/23/2002	11:21	ST II	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	9.74	10.93	1.19	10.34	> 9.74	> 10.93	> 10.34	0	0	0	0.77	3.23	2.60	0	0	0	7	Biogenic	NO	Red clay>pen, hydroids?, stick amps, poly tubes, surf rework
87	B	6/23/2002	11:22	ST I	> 4 phi	3 phi	> 4 phi	UN.SI	0	0	5.2	6.22	1.02	5.71	> 5.2	> 6.22	> 5.71	0	0	0	0.70	2.59	1.44	0	0	0	3	Physical	NO	Red clay>pen, red clay clumps @ surf, dense hydroids, poly tubes
88	A	6/23/2002	11:14	ST I	> 4 phi	3 phi	> 4 phi	UN.SF	0	0	3.58	5.77	2.19	4.68	> 3.58	> 5.77	> 4.68	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO	Red clay>pen, rock or clay chunks-far, burrow?, burrow opening
88	B	6/23/2002	11:15	ST I	> 4 phi	3 phi	> 4 phi	UN.SF	1	0.5	10.18	11.74	1.56	10.96	> 10.18	> 11.74	> 10.96	0	0	0	0.42	3.86	2.77	0	0	0	5	Physical	NO	Red clay>pen, tubes, ox clast, shell-far
89	A	6/23/2002	11:31	ST I	> 4 phi	3 phi	> 4 phi	UN.SI	0	0	9.97	11.97	2	10.97	> 9.97	> 11.97	> 10.97	0	0	0	-99.00	-99.00	-99.00	0	0	0	99	Physical	NO	Red clay>pen, tubes, surf rework, void/burrow?
89	C	6/23/2002	11:33	ST I	> 4 phi	3 phi	> 4 phi	UN.SI	0	0	10.29	11.13	0.84	10.71	> 10.29	> 11.13	> 10.71	0	0	0	0.21	1.54	0.85	0	0	0	3	Physical	NO	Sandy m mixed w/ red clay>pen, red clay chips @ surf, tubes, worm @z?
90	A	6/23/2002	11:37	ST II	> 4 phi	2 phi	> 4 phi	UN.SI	0	0	11.52	11.81	0.29	11.67	> 11.52	> 11.81	> 11.67	0	0	0	0.49	4.28	3.17	0	0	0	8	Physical	NO	Sandy m mixed w/ red clay>pen, sRed clay, red pebbles-far, poly tubes, stick amps, red sed @z: print for report - layering of sand/red clay
90	B	6/23/2002	11:38	ST I on III	> 4 phi	2 phi	> 4 phi	UN.SI	1	0.29	12.22	12.9	0.68	12.56	> 12.22	> 12.9	> 12.56	0	0	0	0.42	3.65.								

Appendix B3
REMOTS Sediment-Profile Imaging Data from the South Reference Area, June 2002 Survey

Station	Replicate	Date	Time	Successional Stage	Grain Size (phi)			Benthic Habitat	Mud Clasts		Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Apparent RPD Thickness (cm)			Methane			OSI	Surface Roughness	Low DO	Comments
					Min	Max	Maj Mode		Count	Avg. Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Count	Mean	Diam				
SREF10	A	6/21/2002	16:12	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.8	4.16	0.36	3.98	0	0	0	0	0	0	>3.8	>4.16	>3.98	0	0	0	7	Physical	NO	Homogenous ambient sand > pen. Small sand waves. RPD>pen
SREF10	C	6/21/2002	16:14	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.18	5.14	0.96	4.66	0	0	0	0	0	0	>4.18	>5.14	>4.66	0	0	0	7	Physical	NO	Homogenous ambient sand. Slightly muddy. Shell material in farfield. Small sand waves. RPD>pen
SREF11	B	6/21/2002	15:34	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	6.79	7.8	1.01	7.3	0	0	0	0	0	0	1.49	3.63	2.34	0	0	0	5	Physical	NO	Homogenous ambient sand > pen. Slight ripple.
SREF11	C	6/21/2002	15:35	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.5	5.66	1.16	5.08	0	0	0	0	0	0	>4.5	>5.66	>5.08	0	0	0	7	Physical	NO	Homogenous ambient sand > pen. Organism at depth? Slight ripple. Shell frag farfield. RPD>pen
SREF14	B	6/21/2002	15:27	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.77	4.84	1.07	4.31	0	0	0	0	0	0	>3.77	>4.84	>4.31	0	0	0	7	Physical	NO	Homogenous ambient sand > pen. Sand dollars in farfield. RPD>pen
SREF14	C	6/21/2002	15:30	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.23	4.84	0.61	4.53	0	0	0	0	0	0	>4.23	>4.84	>4.53	0	0	0	7	Physical	NO	Homogenous ambient sand > pen. RPD>pe
SREF16	B	6/21/2002	15:18	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	5.75	6.18	0.43	5.97	0	0	0	0	0	0	2.35	3.20	2.31	0	0	0	5	Physical	NO	Homogenous ambient sand > pen. Small tubes on surface.
SREF16	C	6/21/2002	15:19	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	2.66	4.21	1.55	3.43	0	0	0	0	0	0	>2.66	>4.21	>3.43	0	0	0	6	Physical	NO	Homogenous ambient sand > pen. RPD>pen. Slight ripple.
SREF18	B	6/21/2002	15:13	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.32	4.71	0.39	4.52	0	0	0	0	0	0	>4.32	>4.71	>4.52	0	0	0	7	Physical	NO	Homogenous ambient sand > pen. shell material & possible surface orgs-far, RPD>pen
SREF18	C	6/21/2002	15:13	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	5.0	5.61	0.61	5.31	0	0	0	0	0	0	>5.0	>5.61	>5.31	0	0	0	7	Physical	NO	Homogenous ambient sand > pen. Possible organism tubes in farfield. RPD>pen
SREF20	A	6/21/2002	15:04	ST I	> 4 phi	3 to 2 phi	4 to 3 phi	SA.F	0	0	6.16	6.43	0.27	6.3	0	0	0	0	0	0	0.28	4.91	2.56	0	0	0	5	Physical	NO	Brown, ambient muddy fine sand, slightly reduced @ depth due to mud content, shell material @ surf.
SREF20	C	6/21/2002	15:07	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	5.88	6.34	0.46	6.11	0	0	0	0	0	0	>5.88	>6.34	>6.11	0	0	0	7	Physical	NO	Homogenous ambient sand > pen. Slight ripple in farfield. RPD>pen
SREF3	A	6/21/2002	16:02	ST I	4 to 3 phi	2 to 1 phi	2 to 1 phi	SAM	0	0	7.89	8.36	0.47	8.12	0	0	0	0	0	0	>7.89	>8.36	>8.12	0	0	0	7	Physical	NO	Homogenous clean ambient medium sand > pen. Slight ripple. RPD>pen
SREF3	C	6/21/2002	16:03	ST I	4 to 3 phi	1 to 0 phi	2 to 1 phi	SAM	0	0	2.89	5.73	2.84	4.31	0	0	0	0	0	0	>2.89	>5.73	>4.31	0	0	0	7	Physical	NO	Homogenous medium to coarse ambient sand >pen, shell material @ surf, sand wave, RPD>pen
SREF4	A	6/21/2002	14:53	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.55	3.8	0.25	3.67	0	0	0	0	0	0	>3.55	>3.8	>3.67	0	0	0	6	Physical	NO	Homogenous ambient sand > pen. Shell frags. Sand dollar in farfield. RPD>pen
SREF4	B	6/21/2002	14:54	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	6.41	6.66	0.25	6.53	0	0	0	0	0	0	>6.41	>6.66	>6.53	0	0	0	7	Physical	NO	Homogenous fine ambient sand > pen. RPD>pen
SREF5	A	6/21/2002	15:44	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	6.66	6.84	0.18	6.75	0	0	0	0	0	0	>6.66	>6.84	>6.75	0	0	0	7	Physical	NO	Homogenous ambient fine sand > pen. Sand dollars. RPD>pen
SREF5	B	6/21/2002	15:45	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	4.79	6.77	1.98	5.78	0	0	0	0	0	0	>4.79	>6.77	>5.78	0	0	0	7	Biogenic	NO	Homogenous ambient sand >pen. sand dollars, surf rough due to sand dollars,sand waves, RPD>pen
SREF8	A	6/21/2002	15:40	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	3.53	4.3	0.37	4.12	0	0	0	0	0	0	>3.53	>4.3	>4.12	0	0	0	7	Biogenic	NO	Homogenous ambient fine sand > pen. Sand dollar, RPD>pen
SREF8	B	6/21/2002	15:41	ST I	4 to 3 phi	2 to 1 phi	3 to 2 phi	SA.F	0	0	6.48	7.05	0.57	6.77	0	0	0	0	0	0	1.35	3.84	2.20	0	0	0	4	Physical	NO	Homogenous ambient sand > pen. Slightly muddy and slightly reduced@dep

APPENDIX C
BENTHIC TAXONOMY DATA

Table C-1
Number of individuals per square meter of each taxon found at each of the fifteen stations in the Red Clay Area.

Taxon name	Station														
	24	26	34	39	43	44	50	51	55	57	64	66	74	78	85
Nucula proxima	425	675	6800	2750	525	1150	600	4600	25	225	3475	300	2550	19400	1650
Levinsonia gracilis	1350	150	2250	1850	50	1025	575	4125	100	250	2150	50	2350	5700	475
Cirratulidae (LPIL)	1075	700	1275	3475	400	1125	725	2125	25	475	375	400	1125	3575	1375
Scoletoma sp. AA	525	100	150	725	0	675	475	1275	25	925	950	575	850	1050	875
Scoletoma verrilli	75	650	175	0	200	575	0	100	0	1925	975	500	1075	650	1375
Pitar morrhuanus	1175	875	350	275	75	75	150	350	25	175	75	875	375	800	100
Scoletoma (LPIL)	700	1050	775	600	125	0	25	750	0	75	875	50	125	550	25
Cossura soyeri	200	0	25	75	0	700	0	1500	0	0	75	0	75	1550	50
Cerastoderma pinnulatum	150	425	250	250	50	175	200	450	50	175	775	100	100	350	175
Nephtys incisa	50	25	225	200	75	200	175	475	50	350	350	0	225	700	200
Eusarsiella zostericola	150	475	100	375	75	75	25	375	0	250	575	150	350	100	100
Pherusa affinis	125	100	100	150	75	50	150	275	0	275	250	25	200	175	275
Polygordius (LPIL)	750	475	450	175	0	0	0	0	0	150	0	125	0	0	0
Mediomastus (LPIL)	275	450	225	350	0	200	0	200	0	0	75	50	125	50	50
Ninoe nigripes	125	0	225	100	25	200	0	75	0	250	125	25	50	250	150
Tellina agilis	550	325	50	0	25	0	25	0	0	0	0	50	25	0	50
Ampelisca vadorum	125	0	0	175	0	0	0	0	0	125	175	0	300	75	25
Tubulanus (LPIL)	725	0	0	100	0	0	0	0	0	25	25	25	0	25	25
Petricola pholadiformis	25	125	50	50	25	25	0	125	0	50	0	100	200	75	25
Prionospio (LPIL)	100	25	175	0	0	0	100	0	0	175	25	0	0	25	250
Spionidae (LPIL)	100	150	0	50	0	100	0	25	0	25	200	0	150	25	25
Unciola irrorata	0	75	25	125	0	0	25	50	0	25	50	25	150	125	100
Aricidea catherinae	275	200	50	0	0	0	0	50	0	0	25	0	50	75	25
Yoldia limatula	0	25	50	25	0	75	75	175	0	0	25	25	50	200	25
Ampelisca (LPIL)	0	150	0	0	0	125	0	100	0	0	0	25	0	225	0
Turbonilla interrupta	0	0	50	300	0	0	25	0	0	50	25	0	75	0	100
Ampelisca abdita	0	0	100	0	0	0	0	0	0	0	0	0	0	475	0
Odostomia (LPIL)	0	0	75	125	25	25	0	25	0	0	150	25	75	25	25
Aphelochaeta marioni	0	0	100	200	0	0	0	75	0	25	0	0	0	150	0
Monticellina dorsobranchialis	0	0	150	0	0	0	0	0	0	0	0	0	25	275	0
Aricidea (LPIL)	200	50	0	0	0	0	0	0	0	0	0	50	25	0	75
Cancer irroratus	0	75	25	75	0	0	50	0	0	0	125	0	0	25	25
Dulichia porrecta	100	0	25	75	0	25	0	125	0	0	50	0	0	0	0
Glycera americana	150	125	0	0	0	0	0	0	0	50	0	0	75	0	0
Mediomastus ambiseta	75	100	75	50	0	0	0	100	0	0	0	0	0	0	0
Mytilus edulis	0	25	0	25	25	0	25	75	25	0	50	0	0	100	0
Pandora arenosa	25	50	0	50	0	0	25	25	0	50	0	25	25	75	0
Actiniaria (LPIL)	25	0	25	0	0	0	0	100	0	50	50	50	0	0	25
Lumbrineridae (LPIL)	0	100	0	0	0	25	200	0	0	0	0	0	0	0	0
Ampharete acutifrons	0	0	25	50	0	50	0	100	0	0	0	0	0	50	25
Ilyanassa trivittata	25	50	25	50	25	0	0	0	0	0	25	0	25	0	75
Scalibregma inflatum	25	25	75	125	0	0	0	25	0	0	0	25	0	0	0
Thracia conradi	0	0	0	0	0	0	0	75	0	0	0	25	0	200	0
Diastylis polita	0	75	0	0	0	25	50	0	25	0	25	50	25	0	0
Prionospio steenstrupi	150	0	0	25	0	0	0	75	0	0	0	0	0	25	0
Bivalvia (LPIL)	50	0	25	0	0	0	0	0	0	50	0	0	0	125	0
Tharyx acutus	125	100	25	0	0	0	0	0	0	0	0	0	0	0	0
Lineidae (LPIL)	25	0	75	0	0	75	0	25	0	0	0	0	0	25	0
Photis macrocoxa	0	25	0	0	0	25	0	125	0	25	0	0	0	25	0
Spiofanus bombyx	75	50	75	25	0	0	0	0	0	0	0	0	0	0	0
Pellucistoma (LPIL)	25	25	150	0	0	0	0	0	0	0	0	0	0	0	0
Spio filicornis	25	0	50	75	0	0	0	0	0	0	0	0	0	25	0
Terebellidae (LPIL)	25	0	0	50	0	0	0	0	0	25	0	0	0	50	25
Astarte borealis	25	0	0	25	25	0	0	50	0	0	0	25	0	0	0
Leptocheirus pinguis	0	0	25	0	0	0	0	0	25	50	25	25	0	0	0
Nephtyidae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	25	0	0	125
Sabellaria vulgaris	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harmothoe imbricata	25	25	0	25	0	0	25	0	25	0	0	0	0	0	0
Nereis succinea	0	0	0	0	0	0	0	0	125	0	0	0	0	0	0
Rhepoxynius epistomus	0	125	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhynchocoela (LPIL)	75	0	0	0	0	0	0	0	0	25	25	0	0	0	0

Table C-1 (continued)

Number of individuals per square meter of each taxon found at each of the fifteen stations in the Red Clay Area.

	Station														
Taxon name	24	26	34	39	43	44	50	51	55	57	64	66	74	78	85
Lyonsia hyalina	75	0	0	0	0	0	0	0	0	0	0	0	25	0	0
Phoronis (LPIL)	0	0	25	0	0	0	0	0	0	0	0	0	25	50	0
Ampharetidae (LPIL)	0	0	0	0	0	0	25	0	0	0	0	25	25	0	0
Apoprionospio pygmaea	0	0	0	0	0	75	0	0	0	0	0	0	0	0	0
Erichthonius rubricornis	0	0	0	0	0	0	25	0	0	0	0	0	0	0	50
Glycera (LPIL)	0	50	25	0	0	0	0	0	0	0	0	0	0	0	0
Ophelina acuminata	0	0	0	0	0	0	0	25	0	0	50	0	0	0	0
Owenia fusiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	75	0
Paraonidae (LPIL)	0	0	0	0	0	0	0	0	0	50	0	25	0	0	0
Rissoidae (LPIL)	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sabellidae (LPIL)	0	0	0	25	0	0	0	25	0	0	0	0	25	0	0
Stenothoe minuta	50	0	0	0	0	0	0	0	0	25	0	0	0	0	0
Asabellides oculata	25	0	0	0	0	25	0	0	0	0	0	0	0	0	0
Corophiidae (LPIL)	25	0	25	0	0	0	0	0	0	0	0	0	0	0	0
Diopatra cuprea	25	25	0	0	0	0	0	0	0	0	0	0	0	0	0
Erichthonius (LPIL)	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0
Exogonella longipedata	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0
Mancocuma stellifera	0	0	0	25	0	0	0	25	0	0	0	0	0	0	0
Microspio sp. A	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0
Nephtys (LPIL)	0	0	0	0	0	0	0	0	0	25	0	0	0	25	0
Nereis (LPIL)	0	0	0	0	25	25	0	0	0	0	0	0	0	0	0
Nereis grayi	0	0	0	25	0	0	25	0	0	0	0	0	0	0	0
Onchidorididae (LPIL)	0	0	0	25	0	0	25	0	0	0	0	0	0	0	0
Photis (LPIL)	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phyllodoce arenae	25	0	0	25	0	0	0	0	0	0	0	0	0	0	0
Sabaco americanus	0	0	0	0	0	0	0	0	0	0	25	0	0	25	0
Spisula solidissima	25	0	0	0	0	0	25	0	0	0	0	0	0	0	0
Ampelisca verrilli	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
Astarte (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0
Chiridotea tuftsi	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0
Dorvilleidae (LPIL)	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0
Drilonereis longa	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0
Edotea triloba	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0
Gastropoda (LPIL)	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0
Glycera robusta	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0
Glyceridae (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
Goniadidae (LPIL)	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0
Leitoscoloplos (LPIL)	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lucina (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0
Mytilidae (LPIL)	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Naticidae (LPIL)	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0
Nuculanidae (LPIL)	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophioglycera gigantea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
Paguridae (LPIL)	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0
Parametopella cypris	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0
Parasterope pollex	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0
Parougia caeca	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Philine quadrata	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Phoxocephalus holbolli	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polycirrus (LPIL)	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0
Scoletoma acicularum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25
Sthenelais limicola	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0
Tellinidae (LPIL)	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0
Thraciidae (LPIL)	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0
Unciola (LPIL)	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yoldia (LPIL)	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0

Table C-2
Number of individuals per square meter
of each taxon found at the five SADMA stations.

Taxon name	Station				
	14	15	16	2	3
Nucula proxima	7475	10575	16750	9725	11550
Cirratulidae (LPIL)	1625	4400	225	525	25
Tharyx acutus	500	4250	0	375	100
Tellina agilis	1175	1575	600	750	525
Mediomastus (LPIL)	550	2475	200	550	175
Pitar morrhuanus	775	600	1375	750	425
Polygordius (LPIL)	100	3375	50	25	25
Levinsonia gracilis	525	450	1325	350	75
Tubificidae (LPIL)	100	850	25	275	50
Mediomastus ambiseta	0	1075	25	0	0
Pellucistoma (LPIL)	0	75	50	275	275
Aricidea (LPIL)	175	125	0	300	0
Spiophanes bombyx	25	225	200	75	25
Aricidea catherinae	50	350	125	0	0
Apoprionospio pygmaea	25	125	25	300	0
Nephtys incisa	100	0	75	125	175
Cossura soyeri	75	200	0	175	0
Mytilus edulis	25	425	0	0	0
Eusarsiella zostericola	0	150	100	150	25
Pherusa affinis	75	75	100	25	0
Yoldia limatula	25	50	125	50	0
Ilyanassa trivittata	150	25	50	0	0
Spisula solidissima	25	50	50	0	100
Phoronis (LPIL)	150	0	25	0	25
Ninoe nigripes	50	75	25	25	0
Cancer irroratus	0	125	0	25	0
Cerastoderma pinnulatum	75	0	75	0	0
Rhynchozoela (LPIL)	0	0	50	100	0
Tubulanus (LPIL)	0	50	25	50	0
Unciola irrorata	50	25	50	0	0
Glycera americana	0	100	0	0	0
Actiniaria (LPIL)	25	0	25	25	0
Chiridotea tuftsi	0	25	50	0	0
Fimbriosthenelais minor	0	0	0	75	0
Monticellina dorsobranchialis	0	0	50	25	0
Pandora arenosa	25	50	0	0	0
Petricola pholadiformis	0	0	25	50	0
Photis macrocoxa	50	25	0	0	0

Table C-2 (continued)
Number of individuals per square meter
of each taxon found at the five SADMA stations.

Taxon name	Station				
	14	15	16	2	3
Scoletoma verrilli	0	25	25	25	0
Spio filicornis	25	50	0	0	0
Spionidae (LPIL)	25	25	25	0	0
Sthenelais limicola	25	25	25	0	0
Aoridae (LPIL)	0	50	0	0	0
Asabellides oculata	0	25	25	0	0
Astarte borealis	25	0	25	0	0
Diastylis polita	0	25	25	0	0
Dipolydora socialis	25	25	0	0	0
Edotea triloba	25	0	25	0	0
Glycera (LPIL)	25	0	0	25	0
Lineidae (LPIL)	0	50	0	0	0
Lyonsia hyalina	25	25	0	0	0
Mancocuma stellifera	25	0	25	0	0
Mytilidae (LPIL)	0	0	0	50	0
Owenia fusiformis	0	25	25	0	0
Pandora (LPIL)	0	0	0	0	50
Sabellaria vulgaris	0	0	0	50	0
Scoletoma (LPIL)	50	0	0	0	0
Veneridae (LPIL)	0	50	0	0	0
Ampelisca (LPIL)	0	25	0	0	0
Ampelisca abdita	25	0	0	0	0
Diopatra cuprea	0	25	0	0	0
Harmothoe imbricata	0	25	0	0	0
Hydrozoa (LPIL)	0	0	0	25	0
Isaeidae (LPIL)	0	25	0	0	0
Leitoscoloplos (LPIL)	0	0	0	25	0
Leptocheirus pinguis	0	0	0	0	25
Lumbrineridae (LPIL)	0	25	0	0	0
Magelona (LPIL)	0	0	25	0	0
Nereis (LPIL)	25	0	0	0	0
Onuphis eremita	0	25	0	0	0
Paranaitis speciosa	0	25	0	0	0
Parougia caeca	0	25	0	0	0
Rissoidae (LPIL)	25	0	0	0	0
Scalibregma inflatum	0	0	25	0	0
Spiochaetopterus oculatus	25	0	0	0	0
Stenothoe minuta	0	0	0	25	0
Unciola (LPIL)	0	0	0	25	0

Table C-3
Number of individuals per square meter of each taxon
found at the three South Reference Area stations.

Taxon Name	Station		
	S4	S8	S14
Tubificidae (LPIL)	425	75	1350
Exogone hebes	150	25	1025
Polygordius (LPIL)	325	75	575
Pellucistoma (LPIL)	50	225	650
Nephtys picta	0	450	275
Mancocuma stellifera	225	175	75
Cauleriella sp. J	175	225	25
Aricidea catherinae	0	150	175
Rhepoxynius epistomus	100	150	50
Rhynchocoela (LPIL)	125	75	75
Tanaissus psammophilus	250	25	0
Monticellina dorsobranchialis	25	0	225
Nucula proxima	50	0	200
Unciola (LPIL)	250	0	0
Chiridotea tuftsi	0	0	225
Aricidea (LPIL)	200	0	0
Syllides longocirrata	25	50	100
Tellinidae (LPIL)	0	175	0
Tellina agilis	150	0	0
Chaetozone setosa	0	25	100
Hippomedon serratus	75	25	25
Pandora arenosa	50	50	25
Parougia caeca	25	25	75
Scoletoma acicularum	50	50	25
Glyceridae (LPIL)	100	0	0
Spiophanes bombyx	25	0	75
Cirratulidae (LPIL)	75	0	0
Edotea triloba	50	25	0
Maldanidae (LPIL)	75	0	0
Ampharete acutifrons	50	0	0
Aricidea wassi	0	0	50
Astarte borealis	0	50	0
Cerastoderma pinnulatum	50	0	0
Dulichia porrecta	0	50	0
Mytilus edulis	25	25	0
Nephtyidae (LPIL)	50	0	0
Nephtys (LPIL)	50	0	0
Paraonidae (LPIL)	25	25	0
Pitar morrhuanus	50	0	0
Scalibregma inflatum	0	0	50
Tellina (LPIL)	0	0	50
Ampelisca (LPIL)	25	0	0
Ampharetidae (LPIL)	0	25	0
Bivalvia (LPIL)	0	0	25
Byblis (LPIL)	0	0	25
Diastylis polita	0	0	25
Drilonereis longa	0	0	25
Echinarachnius parma	0	25	0
Echinoidea (LPIL)	0	25	0
Euchone elegans	25	0	0
Fimbriosthenelais minor	25	0	0
Glycera robusta	0	25	0
Ilyanassa trivittata	0	25	0
Lumbrinerides acuta	25	0	0
Mytilidae (LPIL)	0	25	0
Pitar (LPIL)	0	0	25
Protohaustorius wigleyi	25	0	0
Scoloplos armiger	0	25	0
Spionidae (LPIL)	25	0	0
Spisula solidissima	25	0	0